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HELMINTHOCLADIA FROM INDIA AND NEW ZEALAND

By T. V. Desikachary

University Botany Laboratory, Madras-5

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The genus, *Helminthocladia* J. Ag., includes at the present day about eight species. The ontogeny of the cystocarp has been studied in only three species, *viz.*, *H. calvadosii* (Schmitz, 1896; Kylin, 1930; Rosenvinge, 1909; Hamel, 1930), *H. papenfussii* (Kylin, 1938; Martin, 1939), and *H. hudsoni* (Feldmann, 1939). Even then there are quite a few points and doubts to be cleared (see Papenfuss, 1946, p. 433). There is a definite need for studying as many species as possible of this genus with the help of fluid preserved material.

The writer collected a species of *Helminthocladia* at Okha (see also Boergesen, 1931, p. 7) in January 1955. He has also good material of *H. australis* collected from different parts of New Zealand and the neighbouring islands. He has also with him material of *H. papenfussii* which Prof. Papenfuss had lent him for purposes of comparison. The present paper is based mainly on a study of these materials.

Helminthocladia from India

This form resembled very closely in habit *Helminthocladia calvadosii*. It attains a length of 18–20 inches and its main axis is about $\frac{1}{2}$–1·5 cm. in diam. The alga is highly mucilaginous and sticks to paper. This alga has been collected freshly washed ashore and has not been collected *in situ* (see also Boergesen, 1931). In the present case the writer collected the plant with the attachment intact. The alga is attached by a basal disc and grows on corals, probably in deeper waters (Plate XV, Fig. 1). The branching is pinnate and secondary branches are common. Proliferations were, however, not seen in any great abundance.

The structure of the thallus is as in the other *Helminthocladia* spp., consisting of a compact medulla and a cortex made of radially arranged assimilatory branches. The assimilatory branches are generally up to five times furcate (Text-Fig. 1). The terminal cells of the branches are large and pyriform (Text-Figs. 1, 2). They are 15·3–25·5 μ broad

and 44·2–54·4 μ long. Hairs are very common and their origin is similar to that described by Rosenvinge (1909) in *H. purpurea* and by Martin in *H. papenfussii*. The cells of assimilatory branches have the distinctly stellate chromatophore and a pyrenoid lodged in the upper end (Text-Fig. 2). The chromatophore and the pyrenoid are quite distinct especially in the terminal cells. From the lower cells of the assimilatory branches long narrow rhizoid-like filaments are given off (Text-Fig. 5). These rhizoids run parallel to the medulla and produce clusters resembling the cortical branches.

The alga is monœcious. Boergesen (1931) has observed only female plants. The writer also has collected female plants. Similar variation has been noted in many other species and genera of the Helminthocladiaceæ by other workers.

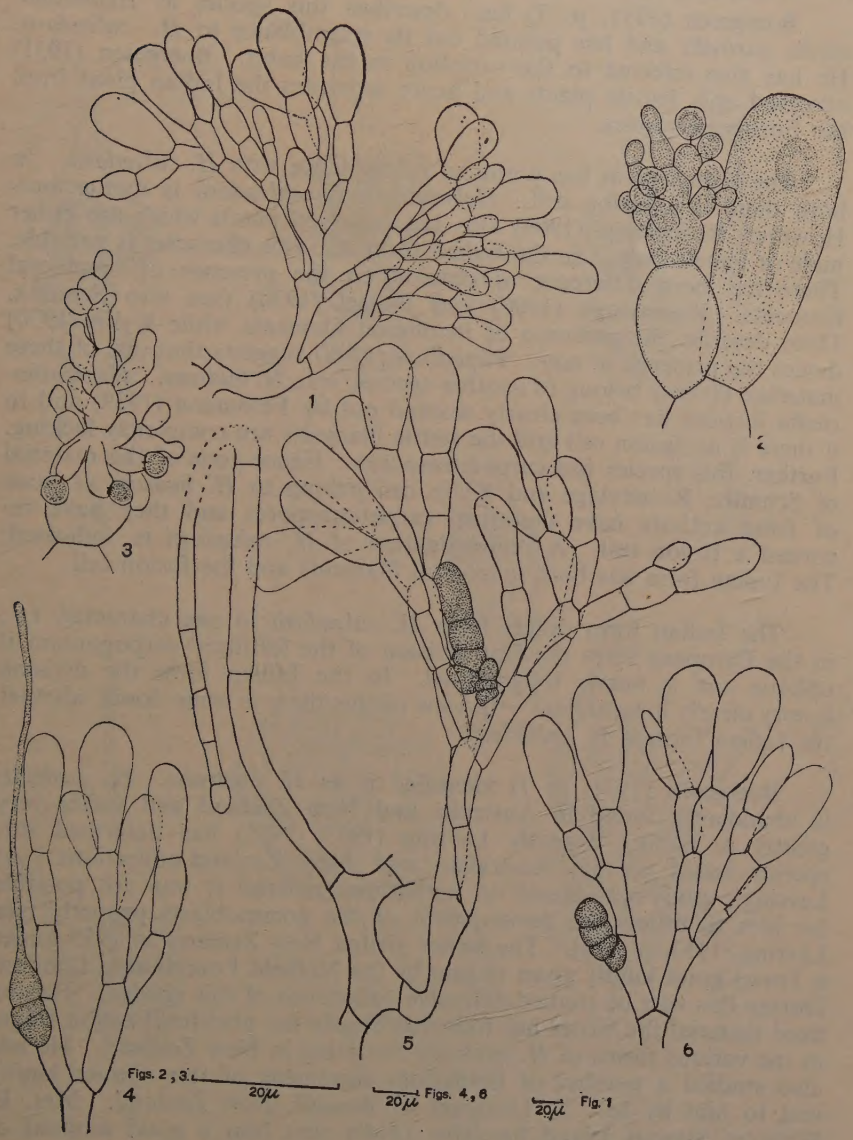
The antheridia are formed at the tips of assimilatory branches (Text-Figs. 2, 3). By repeated division a series of two or three very short cells are formed at the ends. From each of these cells one or more, usually many, antheridial mother cells are formed. From each antheridial mother cell, 2–3 antheridia are cut off, each antheridium producing a single spermatium which is 2·8–3·5 μ in diam.

The carpogonial branches are generally 3-celled (Text-Fig. 4); four-celled branches are also met with (Text-Fig. 6). These are formed laterally on the assimilatory branches below the second and the third furcations (Text-Fig. 5). The carpogonial branch initial is generally clearly seen even when quite young and is differentiated even before the pyriform end cells of the assimilatory branches are distinguishable or developed. The trichogynes are very long and protrude beyond the assimilatory branches. The carpogonial branches are 8·5–11·2 μ broad. Actual fertilization of the carpogonium was not observed.

The fertilized carpogonium at first cuts off the trichogyne (Text-Fig. 11). Then one or more longitudinal divisions take place (Text-Fig. 7). From the daughter cells are developed a number of gonimoblasts which remain very compact for a long time (Text-Figs. 8, 12). The filaments become much branched and produce terminally carpospores. After the formation of a carpospore, the cell below it gives forth a lateral branch which again forms a carpospore terminally. Thus a number of carpospores are formed by repeated branching of the gonimoblast filaments.

With the progress in the formation of the gonimoblast filaments there is a very clear enlargement of the protoplasmic connections between the carpogonial branch cells themselves and the supporting cell. Gradually this widens further and in many cases a fusion cell is ultimately formed (Text-Fig. 12).

Just at the same time as the trichogyne is cut off and the fertilized carpogonium undergoes division, a number of branches are initiated by the cells below and above the supporting cell and by the cells of the neighbouring assimilatory branches. These are the initials of involucral



TEXT-FIGS. 1–6. *Helminthocladia* from India. Fig. 1. Assimilatory branches. Figs. 2, 3. Antheridia. Fig. 4. Carpogonial branch. Figs. 5, 6. Development of the carpogonial branch.

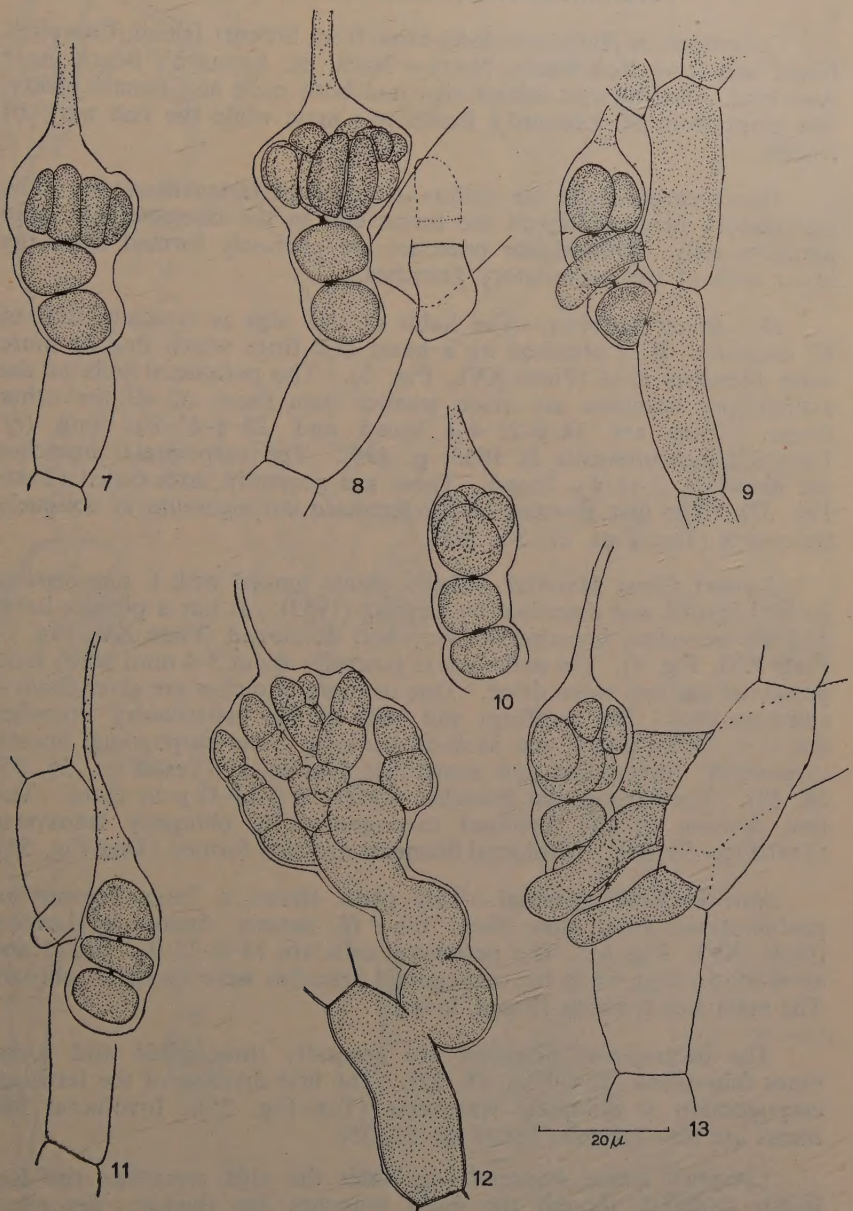
filaments (Text-Figs. 8, 9, 11, 13). Though the involucral filaments are initiated, they are not developed in the Indian form in any great profusion as for instance, in *H. californica*.

Boergesen (1931, p. 7) has described this species as *Helminthocladia australis* and has pointed out its resemblance to *H. calvadosii*. He has also referred to the variation in the habit. Boergesen (1931) observed only female plants and hence separates the Indian plant from the European species.

The Indian plant has points of resemblance with *H. calvadosii*. In both there is a fusion cell. *Helminthocladia calvadosii* is monœcious. However, Rosenvinge (1909) also has observed plants which are either male or female only. In the Indian form also this character is variable. There has been difference of opinion on the presence of involucral filaments. Rosenvinge (1909) and Hamel (1930) (see also Schmitz, 1896) describe the presence of involucral filaments while Kylin (1930) denies the presence of any. Papenfuss (1946) suggests that one of these materials (?) may belong to another species, *viz.*, *H. hudsoni*. *Helminthocladia hudsoni* has been clearly worked out by Feldmann (1939) and in it there is no fusion cell and the sterile filaments are completely lacking. Further, this species has carpotetraspores. Hence none of the material of Schmitz, Rosenvinge and Kylin can belong to *H. hudsoni* as none of these authors have described carpotetraspores and they have recorded a fusion cell. A reinvestigation of *H. calvadosii* is indicated. The Indian form has both involucral filaments and the fusion cell.

The Indian form differs from *H. calvadosii* in one character, *i.e.*, in the European form the first division of the fertilized carpogonium is oblique and is nearly longitudinal. In the Indian form the division is very clearly longitudinal. In view of this there is some doubt whether the Indian form is *H. calvadosii*.

Boergesen (1931, p. 7) identified it as *H. australis*. *H. australis* is abundantly found in Australia and New Zealand and varies very greatly in habit. Recently Levring (1953, 1955) has described this species based on his Australian and New Zealand collections. As Levring's study was based on herbarium material it was not possible for him to follow the development of the gonimoblasts properly (see Levring, 1953, p. 494). The writer visited New Zealand in 1955 under a Travel grant kindly given to him by the Nuffield Foundation, London. During this visit he studied extensive collections of this species. Having fixed material the writer has followed clearly the post-fertilization stages in the various forms of *H. australis* occurring in New Zealand. He has also studied a number of herbarium specimens of this species kindly lent to him by Mr. V. Lindauer of Russell, New Zealand. Mrs. E. Willa of Stewart Island has also kindly sent him a good amount of preserved material of this species. The writer is in agreement with Levring (1953) that this alga shows a large amount of variation in habit though in structure and reproduction there is a very large degree of similarity between the various plants. Hence a general description of the post-fertilization stages is given below and is substantiated by figures showing the various stages in each of the collections.



TEXT-FIGS. 7–13. *Helminthocladia* from India, post-fertilization stages. Figs. 7,10. Division of fertilized carpogonium. Figs. 8, 9, 11, 13. Showing initiation of involucral branches. Fig. 12. Fusion cell.

Helminthocladia from New Zealand

Collections of *Helminthocladia* came from Stewart Island, Campbell Island and from Red Beach, Narrow Neck, St. Leonard's Beach, near Auckland. The Stewart Island alga had both male and female plants. The plant from St. Leonard's Beach was male while the rest were all female.

The construction of the thallus is typical of *Helminthocladia*. The assimilatory filaments in all the forms end in the characteristic large pyriform cells. Rhizoid-like branches are profusely formed from the lower cells of the assimilatory branches.

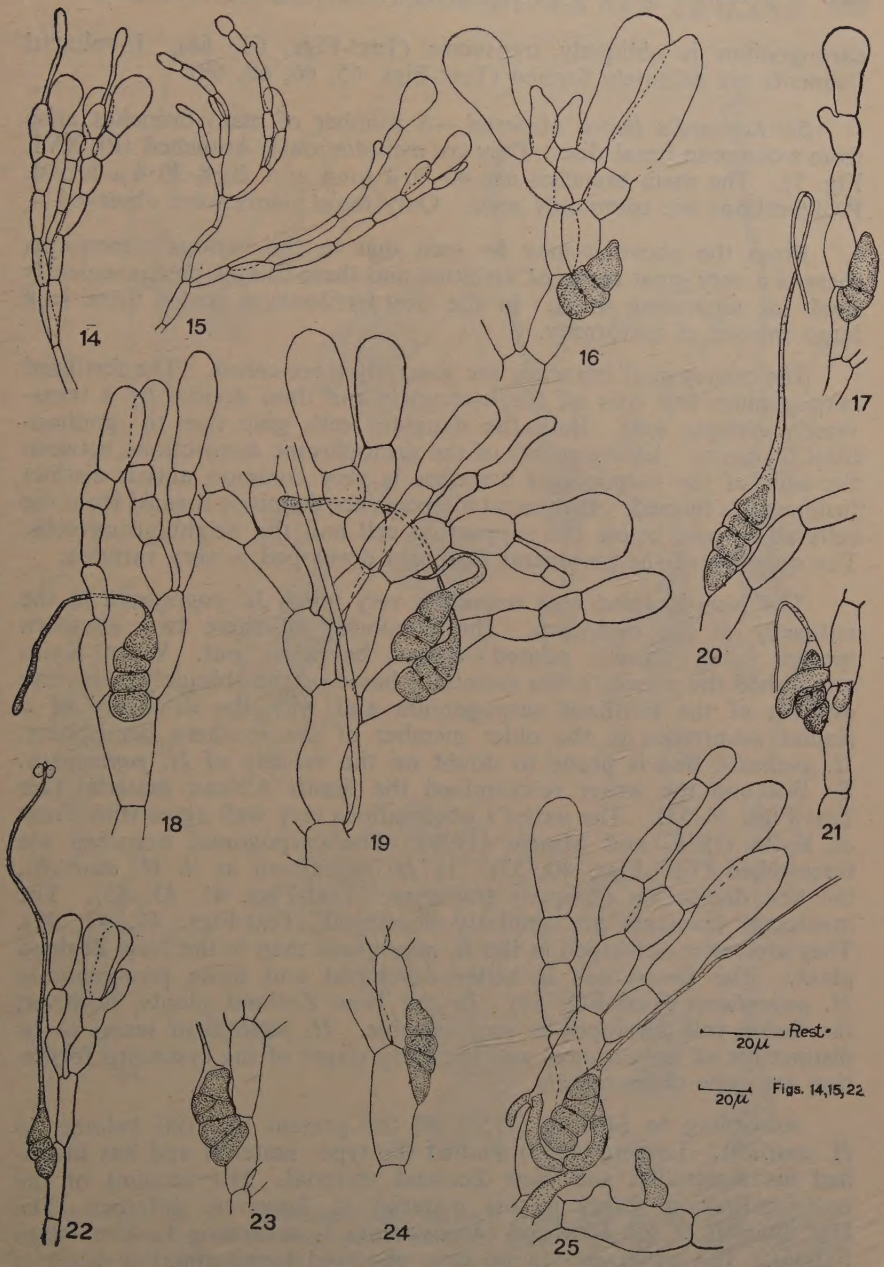
Red Beach Material.—The habit of this alga is typically that of *H. australis*. It is attached by a basal disc from which one or more main branches arise (Plate XVI, Fig. 3). The peripheral cells of the assimilatory branches are much smaller than those of all the other forms. They are 14·0–22·4 μ broad and 28·8–43·2 μ long (*cf.* Levring's measurements in 1953, p. 494). The carpogonial branches are about 11·2–14·4 μ broad. These are generally three-celled (Text-Fig. 37). The first division of the fertilized carpogonium is obliquely transverse (Text-Figs. 27, 30, 36).

Stewart Island Material.—These plants agreed with f. *ramosissima* so well figured and described by Levring (1953). It has a pinnate habit and the secondary branches are very well developed (Plate XV, Fig. 2; Plate XVI, Fig. 4). The main axis is generally about 3–4 mm. when fluid preserved and less when dried. One or more branches are given from a common disc. The pyriform end cells of the assimilatory branches are 21·6–25·2 μ broad, and 54·0–64·8 μ long. The carpogonial branch is generally three-celled and sometimes four-celled (Text-Figs. 54, 55, 58, 59). The carpogonial branches are (12·6–) 14–18 μ in diam. The first division of the fertilized carpogonium is obliquely transverse (Text-Figs. 58, 59). Involucral filaments are also formed (Text-Fig. 55).

Narrow Neck Material.—This plant shows a large amount of proliferations, even more than the '*H. tumens*' figured by Levring (Plate XVI, Fig. 6). The peripheral cells are 14·8–25·9 μ broad and 44·4–55·5 μ long while the carpogonial branches were about 11 μ broad. The main axis is about 10 mm. broad.

The carpogonial branches are generally three-celled and sometimes four-celled (Text-Figs. 18, 22). The first division of the fertilized carpogonium is obliquely transverse (Text-Fig. 25). Involucral filaments are also formed (Text-Figs. 21, 25).

Campbell Island Material.—In habit the alga resembles the Red Beach material, though the main branches are thicker. Secondary branches are very common (Pl. XVI, Fig. 5). The peripheral cells of the assimilatory filaments are 22·5–29·6 μ broad and 55·5–74 μ long. The carpogonial branches are about 10 μ broad. The carpogonial branches are three-celled (Text-Figs. 67, 70). The first division of the fertilized



TEXT-FIGS. 14–25. *Helminthocladia australis* from Narrow Neck. Fig. 14. Young assimilatory branch. Fig. 15. Apical portion of an axial filament. Figs. 16, 17, 24. Young carpogonial branches. Figs. 18, 19. Carpogonial branches. Figs. 19, 20, 22. Showing trichogyne being cut off after fertilization. Figs. 21, 23. 25. First division of the fertilized carpogonium and the initiation of the involucral branches.

carpogonium is obliquely transverse (Text-Figs. 65, 68). Involucral filaments are definitely formed (Text-Figs. 65, 66, 68, 69).

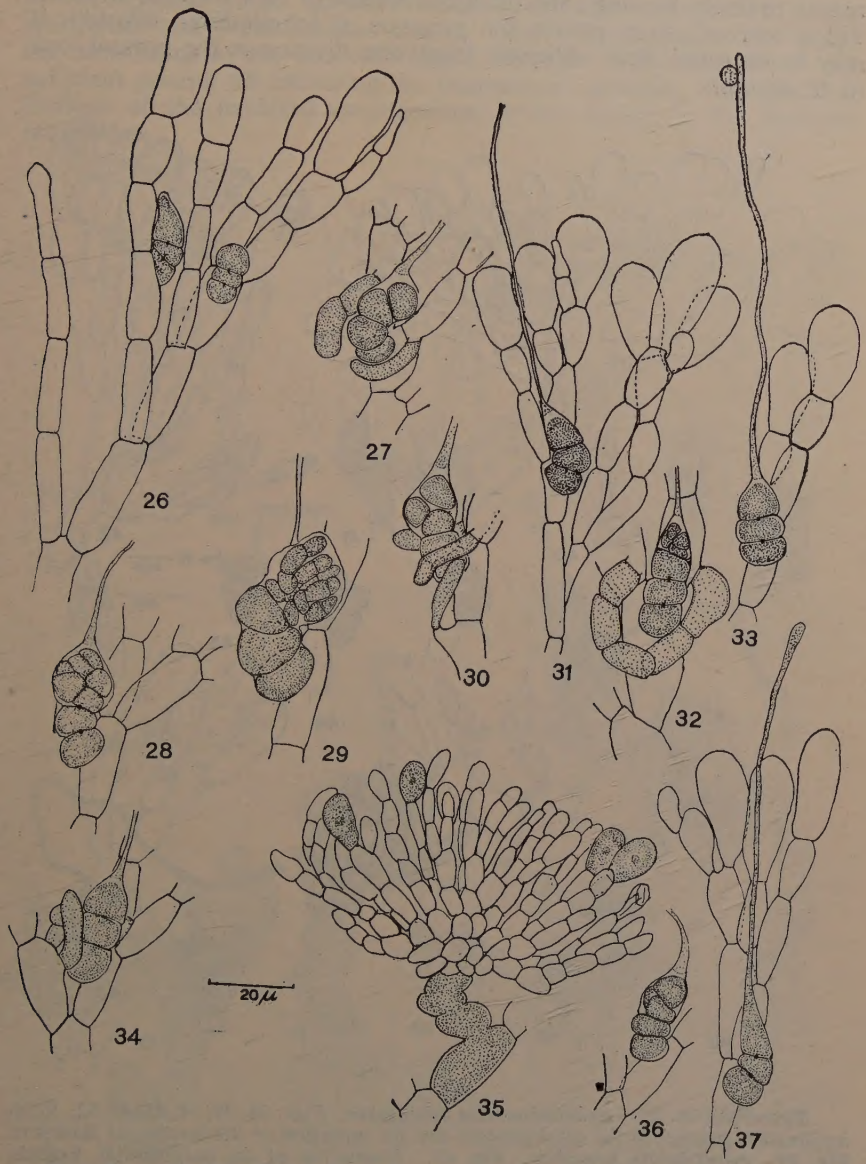
St. Leonard's Beach Material.—A number of main branches arise from a common basal disc. They are dichotomously branched (Pl. XVI, Fig. 7). The main branches are 40–56 μ long and 20·8–30·4 μ broad. Proliferations are commonly seen. Only male plants were observed.

From the above it may be seen that in the various dimensions there is a very great range of variation and these cannot be conveniently used for separating them. In the post-fertilization stages there is a large amount of uniformity.

The carpogonial branches are generally three-celled. The fertilized carpogonium first cuts off the trichogyne and then divides by a transversely oblique wall. Both the daughter cells give rise to gonimoblast filaments. Enlargements of the protoplasmic connections between the cells of the carpogonial branches is very common and a distinct fusion cell is formed. Involucral filaments are definitely formed from the cells above and below the supporting cell and the neighbouring cells. The quantity of the involucral filaments developed is very variable.

The New Zealand alga resembles very much *H. papenfussii* in the ontogeny of the cystocarp. The possibility of these two southern species being closely related cannot be ruled out. When Kylin established the species it was essentially based on the obliquely transverse division of the fertilized carpogonium and with the discovery of a similar occurrence in the older member of the southern hemisphere, *H. australis*, one is prone to doubt on the validity of *H. papenfussii*. To this end the writer re-examined the South African material (see Text-Figs. 38–53). The writer's observations very well agree with those of Kylin (1938) and Martin (1939). The carpogonial branches are three-celled (Text-Figs. 40, 53). In *H. papenfussii* as in *H. australis*, the first division is obliquely transverse (Text-Figs. 41, 43, 45). The involucral filaments are similarly developed (Text-Figs. 46, 47, 49). They are better developed in the *H. papenfussii* than in the New Zealand plant. The fusion cell is better developed and more prominent in *H. papenfussii* (Text-Fig. 51). In the New Zealand plants, however, the fusion cell developed is very variable. *H. papenfussii* seems to be distinct for all appearances and the early stages of the cystocarp formation are quite characteristic.

According to Levring (1953) all the present material belongs to *H. australis*. Levring (1953) studied the type material and has identified his Australian and New Zealand material. His account of the post-fertilization stages in his material is, however, different. The first division of the fertilized carpogonium is according to him longitudinal. The writer has in no case observed longitudinal division in the New Zealand material. Levring himself states that he did not have fluid material and that he could not describe the early stages in gonimoblast development clearly. The writer is of the opinion that the Australian form of *H. australis* must be studied with the help of



TEXT-FIGS. 26–37. *Helminthocladia australis* from Red Beach, New Zealand. Fig. 26. Formation of the carpogonial branch. Figs. 27–34, 36. Post-fertilization changes in the carpogonium and the initiation of the involucral filaments. Fig. 35. Cystocarp showing fusion cell. Fig. 37. Carpogonial branch.

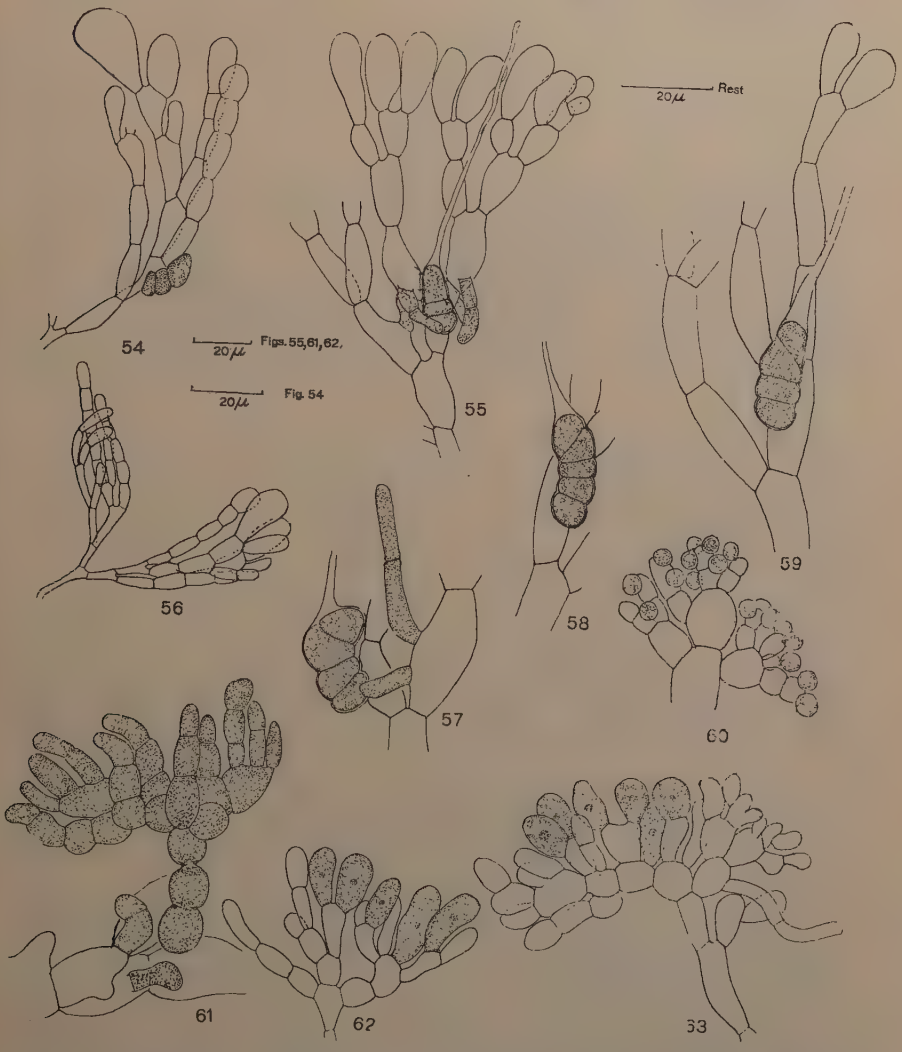
preserved material to settle this point. In the event of the longitudinal division being proved the rule in the Australian material, the New Zealand form must be separated from the Australian one. There is no

reason to doubt Levring's specific identification of New Zealand material. Till a reinvestigation proves the presence of longitudinal division, it may be accepted that obliquely transverse division is the normal one in *H. australis*.

TEXT-FIGS. 38–53. *Helminthocladia papenfussii*. Figs. 38, 39, 41, 43–49, 52. Post-fertilization changes in the carpogonium and the initiation of the involucral filaments. Fig. 40. Assimilatory branches. Fig. 42. Formation of the carpogonial branch. Fig. 50. Cystocarpic branches with carpospores. Fig. 51. Young cystocarp with fusion cell. Fig. 53. Carpogonial branch.

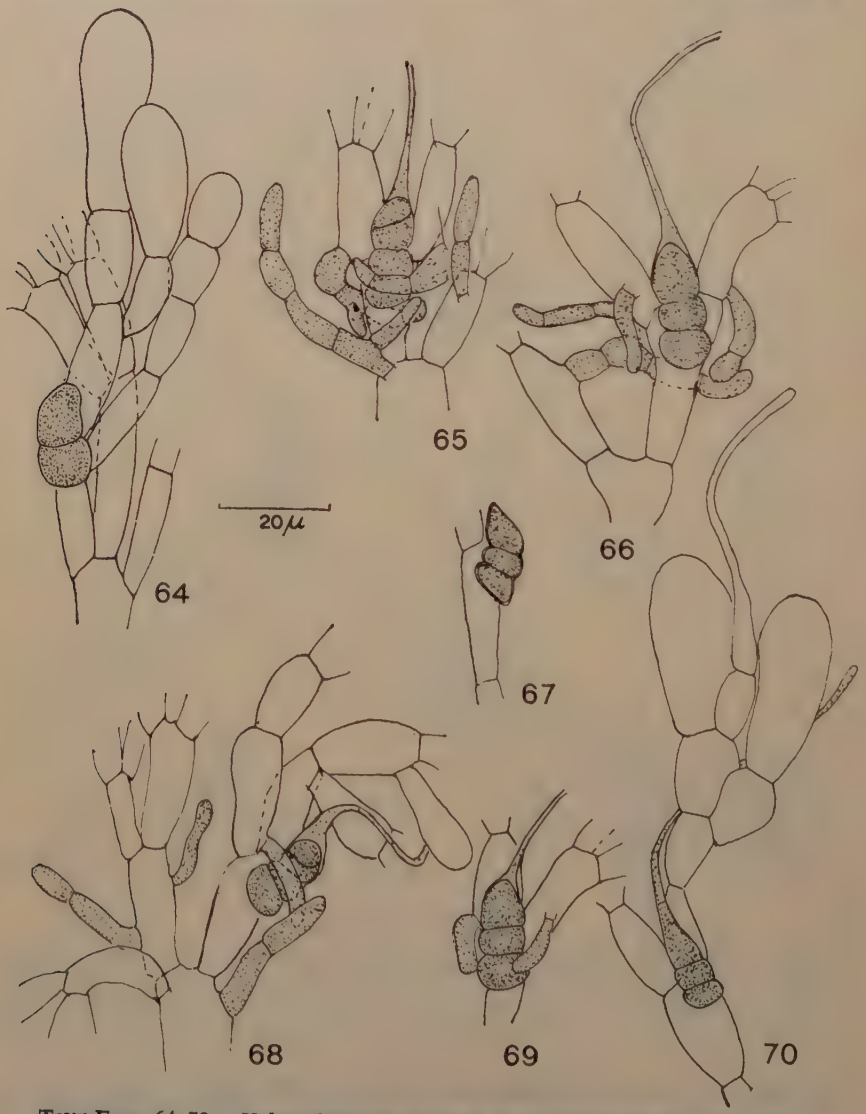
Levring (1953) seeks to exclude Okamura's (1923, p. 21) report of *H. australis* from Japan. According to him it does not appear to be identical with Australian and New Zealand plants. The very typical large end cells of the assimilatory filaments are considerably smaller

in the Japanese form. In other details they seem to be similar to the Australian and New Zealand plants. The present author has found the dimensions of the end cells highly variable and hence there is not sufficient ground for excluding the Japanese *H. australis*. The plane of division of the fertilized carpogonium is not known in the Japanese material.



TEXT-FIGS. 54–63. *Helminthocladia australis* from Stewart Island. Fig. 56. Young assimilatory branches. Fig. 54. Formation of the carpogonial branch. Fig. 60. Antheridia. Figs. 55, 57–59. Post-fertilization changes in the carpogonium and the formation of involucral filaments. Fig. 61. Developing cystocarp with fusion cell. Figs. 62, 63. Cystocarpic branches with carpospores.

The above study of the New Zealand material has further shown that the Indian material is not similar to *H. australis*. The writer does not find any justification for separating the Indian form from *H. calvadosii*. It is now identified as *H. calvadosii*. On account of the slight difference in the post-fertilization stages it is kept as f. *indica*. A



TEXT-FIGS. 64–70. *Helminthocladia australis* from Campbell Island. Figs. 64, 67. Formation of carpogonial branches. Figs. 65, 66, 68 and 69. Post-fertilization changes in the carpogonium and the formation of involucral filaments. Fig. 70. Carpogonial branch.

reinvestigation of *H. calvadosii* from Europe is very necessary to check up the details of post-fertilization stages given by Rosenvinge (1907) and Kylin (1930) especially on the development of the involucral filaments.

H. calvadosii f. *indica*.—Similar to the type. First division of the fertilized carpogonium longitudinal.

Similis typicæ speciei; divisio prima carpogonii fertilissati longitudinalis.

Typus lectus.—Okha in statu Bombay, in India.

Conclusion

The genus *Helminthocladia* has at the present day eight species: (1) *H. calvadosii*, (2) *H. australis*, (3) *H. papenfussii*, (4) *H. hudsoni*, (5) *H. yendoana*, (6) *H. gracilis*, (7) *H. californica* and (8) *H. densa*. Of these the first three have already been discussed. The fourth has been fully investigated (Feldmann, 1939). The first division of the fertilized carpogonium is oblique very like in *H. calvadosii*. There is a fusion cell and the involucral filaments are not developed. *H. hudsoni* is very distinct from the rest of the species by the formation of carpotetraspores instead of carpospores.

Helminthocladia californica Kylin was first described as *H. australis* f. *californica*. It is a diœcious plant, and the cystocarps are provided with a prominent involucre. The nature of the first division of the fertilized carpogonium is not known. This species awaits detailed study.

Very little is known of the post-fertilization stages in *H. gracile* Gardner (1924), and *H. yendoana* Narita. Recently Levring (1953) studied *H. densa*. His comments on this species are quoted below:

"I have collected a few specimens, which agree perfectly with the species Harvey has placed under this name in his exsiccata. Schmitz has referred the species to *Helminthocladia*. My own study of the anatomy and fruit development has also shown that it is a true representative of the genus."

"The thallus is about 10–20 cm. high, repeatedly dichotomously branched with numerous side branches, cylindrical, gelatinous in older parts 1–2 mm. thick. Slender. Colour brownish or yellowish red, also when dried. The carpogonial branches are three-celled. They are developed as accessorial branches from a cell in the middle part of the assimilatory filaments. The young carpogonial branches are developed just below the top of the branches. After fertilisation the carpogonium is at first divided into two cells. From the upper one of these are developed a number of branches bearing the carpospores. No fusion between the supporting cell, carpogonial branch cells or gonimoblast cells has been observed. The gonimoblast is not surrounded by sterile filaments. The development of the gonimoblast thus agrees very well with the type of *H. calvadosii* described by Kylin 1930 (p. 6)."

"I have also seen authentic material of *Nemalion insigne*, which was supposed by Harvey himself to be a synonym of this species. I can only agree with him in this opinion. According to Harvey tetrasporangia are formed in the terminal cells of the peripheral branches. Since I have not been able to find this, neither in Harvey's nor in my own specimens, Harvey's remark is probably due to a mistake."

From the above it appears that *H. densa* differs from the other *Helminthocladia* spp., in many important respects: (1) The characteristic end-cells of the assimilatory branches seem to be lacking (see his Fig. 25 F) and (2) the post-fertilization stages are more like those of *Helminthora*. In all the species of *Helminthocladia* so far fully studied, whatever be the plane of division, both the resultant cells partake in the formation of gonimoblast filaments (see Papenfuss, 1947, p. 432). In *Helminthocladia densa* according to Levring, the case is just like in *Helminthora*, *i.e.*, only the upper cell takes part in the formation of gonimoblast filaments. Until further re-examination proves otherwise, *H. densa* should be transferred to *Helminthora* as *Helminthora densa* (Harv.) comb. nov.

The case of *H. densa* naturally leads on to a consideration of the distinction between *Helminthocladia* and *Helminthora*. Till Kylin's discovery of *Helminthocladia papenfussii*, it could have been said that longitudinal division of the fertilized carpogonium is characteristic of *Helminthocladia*. Other characters such as the nature of the medulla and the presence or absence of involucral filaments are of not much use. Now that involucral filaments definitely exist in *Helminthocladia* (*e.g.*, *H. californica*) and that both longitudinal and transverse divisions of the fertilized carpogonium are known, search for a reliable character must be made elsewhere. The characteristic large, pyriform end-cells of the assimilatory filaments with a stellate chromatophore placed in the end position are not seen in *Helminthora*. Papenfuss (1947, p. 432) draws a fine distinction between the two genera based on the development of the gonimoblast from the products of the fertilized carpogonium. In *Helminthocladia* both the daughter cells take part, while in *Helminthora* only the upper of the two daughter cells takes part in the formation of gonimoblast filaments. In the writer's opinion these two characters are sufficiently stable characters and the genus *Helminthocladia* should be defined by these characters.

Summary

Helminthocladia spp. collected from India and New Zealand are described and the structure and the development of the cystocarp is discussed.

The Indian plant, hitherto identified as *H. australis*, is now identified as *H. calvadosii* f. *indica* as in the Indian plants the fertilized carpogonium undergoes longitudinal division.

The New Zealand forms of *H. australis* are described in great detail and the variation in habit and the uniformity in the post-fertilization

stages are described. The fertilized carpogonium divides by a transversely oblique wall.

In both the Indian and New Zealand forms the two daughter cells of the fertilized carpogonium partake in gonimoblast formation. Involucral filaments are formed, though meagrely, from the cells above and below the supporting cell.

A comparison is made with the other species of *Helminthocladia*.

It is suggested that *Helminthocladia densa* be transferred to *Helminthora*.

Two features, *viz*., (1) the presence of large pyriform peripheral cells of the assimilatory branches and (2) the two daughter cells formed by the division of the fertilized carpogonium partaking in gonimoblast formation, are chosen as the essential characteristic features of the *Helminthocladia*.

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The writer expresses his grateful thanks to Prof. T. S. Sadasivan, Director of the University Botany Laboratory, Madras, for kind facilities.

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EXPLANATION OF PLATES XV AND XVI

PLATE XV

FIG. 1. *Helminthocladia* from India. Habit of a female plant. 2/5 natural size.

FIG. 2. *Helminthocladia australis* f. *ramosissima* from Stewart Island. A female plant.

PLATE XVI

FIG. 3. *Helminthocladia* from Red Beach, New Zealand. A female plant.

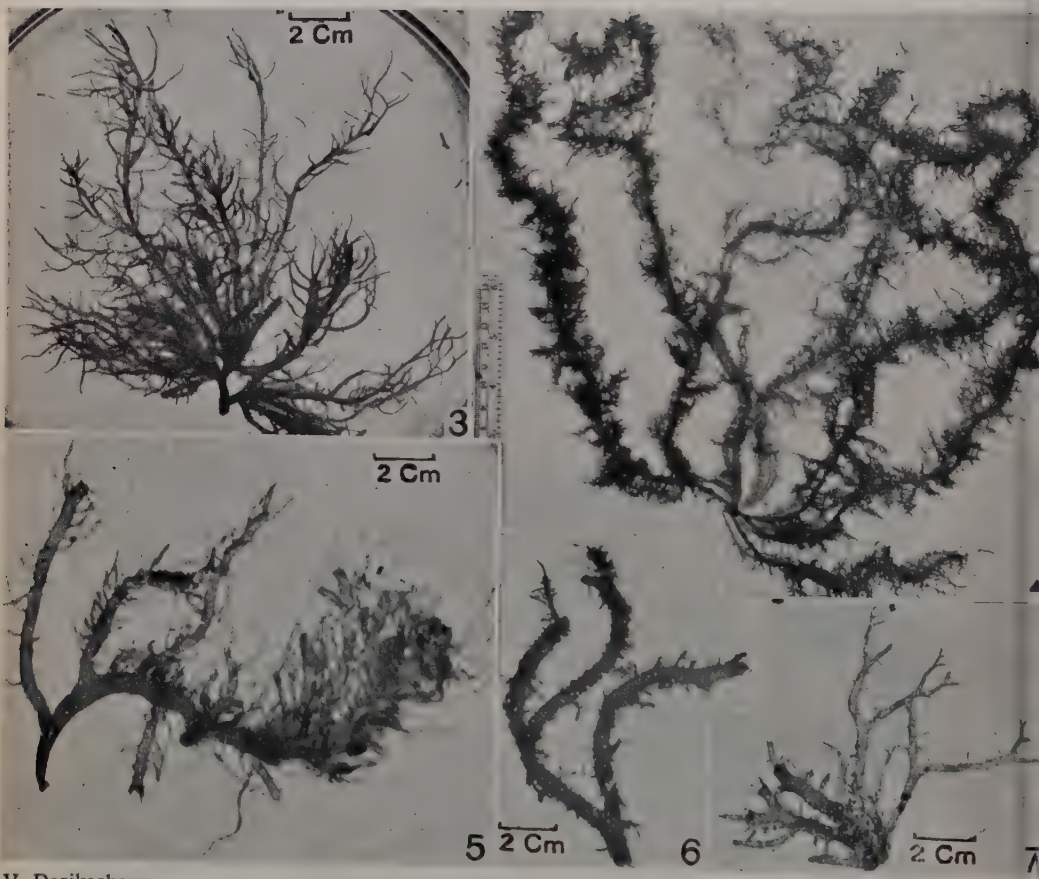
FIG. 4. *Helminthocladia australis* f. *ramosissima* from Stewart Island. A female plant.

FIG. 5. *Helminthocladia* from Campbell Island. Female plant.

FIG. 6. *Helminthocladia* from Narrow Neck near Auckland, New Zealand. A portion of the plant showing proliferation.

FIG. 7. *Helminthocladia* from St. Leonard's Beach. Habit of a male plant.

T. V. Desikachary



T. V. Desikachary

POST-FERTILISATION DEVELOPMENT IN *LIAGORA*

By T. V. Desikachary and M. S. Balakrishnan

University Botany Laboratory, Madras-5

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Papenfuss (1946, pp. 433, 434), Balakrishnan (1955) and Desikachary (1956) have pointed out the necessity for studying as many species of *Liagora* as possible with the help of fluid preserved material. The present paper gives an account of four species of *Liagora*, *viz.*, *L. viscida* (Forssk.) Lamouroux, *L. ceranoides* Lamouroux, *L. harveyiana* Zeh and *L. mucosa* Howe.

L. viscida (Forssk.) Lamouroux

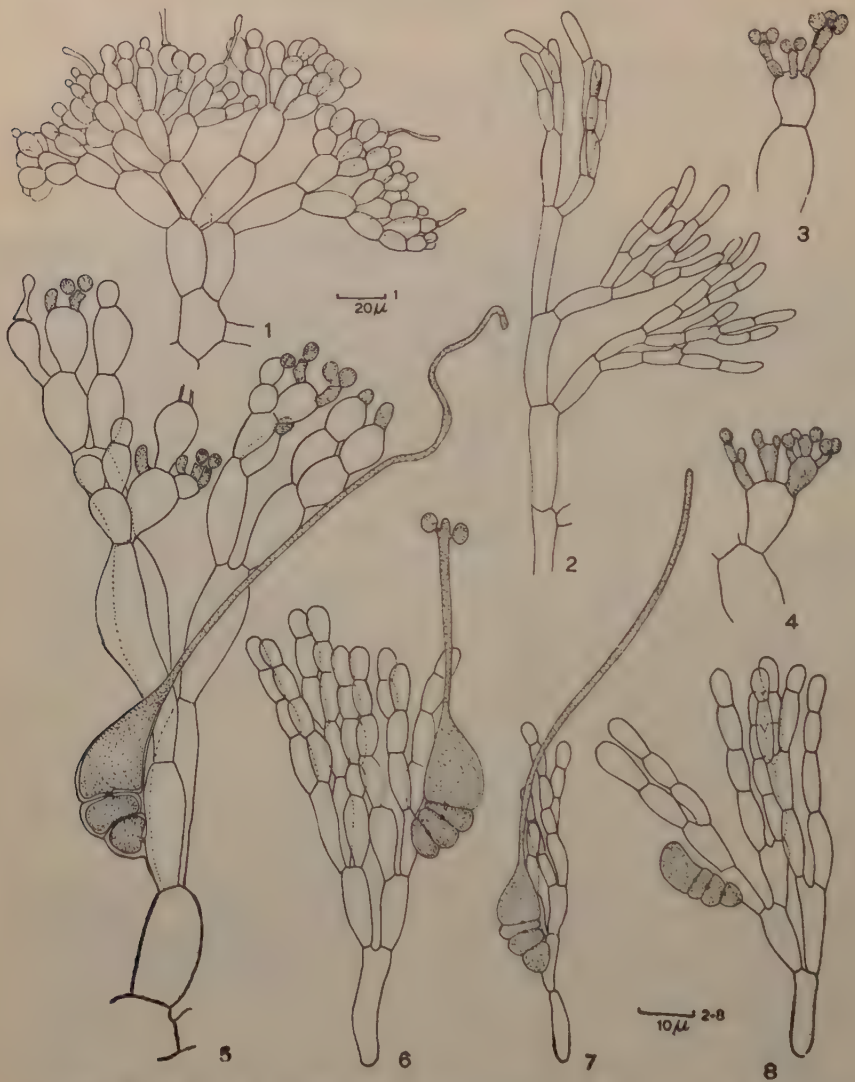
(Text-Figs. 1–14)

This species is the lectotype of the genus (see Abbott, 1945, p. 146). Kylin (1930) described post-fertilisation changes in this alga. According to him, a fusion cell is formed after fertilisation and the cystocarp lacks an envelope of sterile filaments (involucre). Interest is aroused in this species owing to the fact that in many species of *Liagora* involucral filaments are definitely formed, though meagrely in some. Even in the other species investigated by Kylin, *L. tetrasporifera* Boergesen, involucral filaments are formed (see Boergesen, 1927); this species, however, lacks a fusion cell. Further Hamel (1930, p. 76) has reported the formation of sterile involucral filaments from the sterile cells of the carpogonial branch in *L. viscida*.

Kylin (*loc. cit.*) based his studies on material of *L. viscida* from Banyuls-sur-Mer in France. Prof. G. F. Papenfuss very kindly collected and sent to the authors very fine material of this species collected from the same locality (Banyuls, coast of Albers, S. France, June 1954) and suggested its study. The following is a short account of this species.

The alga is very short and up to 2–3 cm. in height. At the broadest portion it is up to 2 mm. wide. It is repeatedly dichotomously branched (Plate XVII, Fig. 3). Proliferations are absent.

The thallus has the characteristic structure of the Helminthocladiaceæ. The medullary filaments when young are about 5 μ broad. The cortical branches or the assimilatory filaments are 5–6 times furcate; in the upper portions they are trichotomous or tetrachotomous, giving rise to a bushy appearance (Text-Fig. 1). The cells in the lower portions of the assimilatory branches are subcylindrical to elongate barrel-shaped, and in the end portions the cells are ovate. Assimilatory filaments when young are 2·5–3 μ broad and later when mature 14–16 μ



TEXT-FIGS. 1–8. *L. viscida*. Fig. 1. Assimilatory filament. Fig. 2. Terminal portion of medullary filament showing the formation of young assimilatory branches. Figs. 3, 4. Antheridia. Figs. 5–7. Carpogonial branches. Fig. 6 showing the trichogyne with two attached spermatia. Fig. 8. Young assimilatory filament with developing carpogonial branch.

broad in the lower portions. The cells are 1½–3 times as long as broad. Rhizoids are commonly present.

The alga is monœcious. The antheridia are borne terminally (Text-Figs. 3, 4). The terminal cells of the assimilatory filaments form

two to three antheridial mother cells. The antheridial mother cells are generally long and narrow and produce 2–4 antheridia. The antheridia are 2–2·5 μ in diameter.

TEXT-FIGS. 9–14. *L. viscida.* Fig. 9. Fertilised carpogonium with the trichogyne cut off; note initiation of involucral filaments. Figs. 10, 14. Showing the transverse division of the fertilised carpogonium, initiation of involucral filaments and enlargement of protoplasmic connections. Figs. 11, 12. Gonimoblast filaments showing terminal carpospores. Fig. 13. Showing the well-developed involucral filaments, the developing gonimoblast and the enlargement of the protoplasmic connections.

The carpogonial branches are formed even before the cortical aments are fully developed (Text-Fig. 8). They are generally four-celled though three-celled ones are also seen (Text-Figs. 5–7). The carpogonial branches are 6·5 to 9 μ broad. The carpogonium itself is broader than the rest of the branch and is up to 11·7 μ broad. The trichogyne is generally long and projects outside the assimilatory filaments.

The changes in the fertilised carpogonium are very similar to those described so well by Kylin (1930) (Text-Figs. 9, 10, 13, 14). At first, the trichogyne is cut off (Text-Fig. 9). The fertilised carpogonium then undergoes division transversely to form two almost equal cells (Text-Fig. 14). From the upper daughter cell the gonimoblast filaments are formed (Text-Fig. 13). These become much branched and form carpospores at the tips (Text-Figs. 11, 12). The lower daughter cell of the fertilised carpogonium does not take part in the formation of the gonimoblast. The gonimoblast filaments are 2–2·5 μ broad. The carpospores are 8–9 μ broad and 14–16 μ long.

Simultaneous with the formation of the gonimoblast filaments the protoplasmic connections between the sterile cells of the carpogonial branch, the lower daughter cell of the fertilised carpogonium and the supporting cell get enlarged (Text-Figs. 9, 13). Finally a fusion cell involving all these cells is formed.

The cystocarp of *L. viscida* has a definite envelope of involucral filaments (Text-Fig. 13). These are initiated soon after fertilisation (Text-Figs. 9, 10, 14). The cells above and below the supporting cell as also the cells adjacent to it cut off involucral initials. These initials produce repeatedly branched filaments which form a sterile envelope around the gonimoblast filaments. The involucral filaments are 2·5–4 μ broad.

The above account of post-fertilisation changes agrees very much with Kylin's (1930). But in one aspect it differs from his account. According to Kylin, the cystocarp lacks an envelope of involucral filaments. In the present investigation involucral filaments have been definitely and clearly observed. In this respect there is agreement with Hamel's account of *L. viscida*. Hamel (1930), however, says that the involucral filaments arise from the sterile cells of the carpogonial branch. In the present investigation the involucral filaments have never been observed to arise from either the sterile cells of the carpogonial branch or even from the supporting cell.

In the accounts of the other *Liagora* spp. that follow, only essential details are given.

L. ceranoides Lamouroux

(Text-Figs. 15–27)

This alga was collected from the Andamans by Dr. H. S. Rao and the writers studied the material through the kind courtesy of

TEXT-FIGS. 15–27. *L. ceranoides*. Figs. 15, 17. Old and young assimilatory branches. Fig. 19. Axial filament showing the formation of assimilatory branches. Figs. 16, 18. Carpogonial branches. Figs. 20, 22. Showing the initiation of involucral filaments and the first division of the fertilised carpogonium. Fig. 21. Initiation of gonimoblast filaments. Figs. 23, 24. Gonimoblast filaments with terminal carpospores. Figs. 25–27. Showing the fusion cell and involucral filaments.

Prof. M. O. P. Iyengar. The alga appears to be *L. ceranoides* f. *pulverulenta* (Ag.) Yamada (Plate XVII, Fig. 2). It agrees very well with the description given by Abbott (1945, pp. 157–59; see also Boergesen, 1916, p. 83).

The plants are about 4 cm. high and regularly dichotomously branched. The proliferations, however, are not common. No annulation is visible (*cf.* Dawson, 1952). The assimilatory filaments are up to 8 times furcate and the cells are 3–4 μ broad when young and 7·5 to 12 μ broad when mature (Text-Figs. 15, 17). They are up to 8 times as long as broad in the basal portions of the mature assimilatory filaments. In the upper portions the cells are ovate and only 1–1½ times as long as broad.

The plants are diœcious.

The carpogonial branches are four-celled and borne laterally (Text-Figs. 16, 18). These are 12–15 μ broad. The carpogonium itself is narrower than the sterile cells below and is only 8–10 μ wide. The carpogonial branches are much curved.

The post-fertilisation changes are similar to those seen in *L. viscida* described earlier. The first division of the fertilised carpogonium is transverse and the upper daughter cell alone takes part in the formation of the gonimoblast filaments (Text-Figs. 21, 22). The gonimoblast filaments are 3–4 μ broad and the carpospores are formed terminally on them (Text-Figs. 23, 24). The carpospores measure 18 × 15 μ.

Here, as in *L. viscida*, the protoplasmic connections between the sterile cells of the carpogonial branch and the supporting cell get widened and the fusion cell so formed is more prominent than in *L. viscida* (Text-Figs. 25–27).

In the present form, as in many other *Liagora* species, involucral filaments are initiated soon after fertilisation from the cells below and above the supporting cells and also the cells adjacent, as has been described for *L. pulverulenta* (= *L. ceranoides* f. *pulverulenta*) by Boergesen (1916, p. 83) (Text-Figs. 20, 22, 25–27). The involucral filaments do not, however, envelope the gonimoblast filaments which remain exposed (Text-Fig. 26).

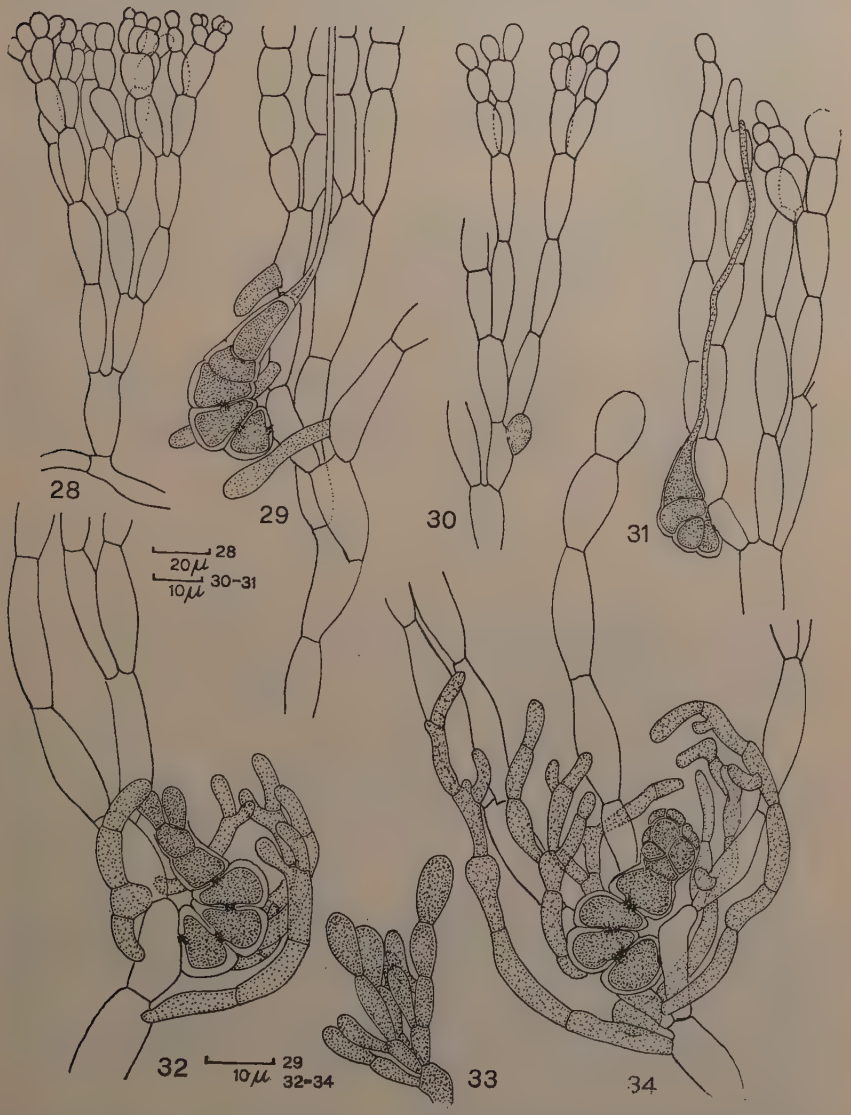
L. harveyiana Zeh

(Text-Figs. 28–34)

This species was collected at Stanmore Bay, New Zealand. It has been very well described by Levring (1953, p. 501). Having fluid material, the writers studied the alga to note the presence of a fusion cell and the mode of initiation of the involucral filaments.

The alga is dichotomously branched and up to 10 cm. high (Plate I. Fig. XVII). It lacks lateral proliferations. The medullary filaments are 10–13 μ broad. The assimilating filaments are 6–8 times furcate (Text-Fig. 28). The cells are 8–11 μ broad in the lower regions and

5–7 μ wide at the tips. They are up to 3 times as long as broad in the lower portions and $1\frac{1}{2}$ times as long as broad in the upper portions.



TEXT-FIGS. 28–34. *L. harveyiana*. Fig. 28. Assimilatory filament. Fig. 29. First division of the fertilised carpogonium and the initiation of the involucral filaments. Fig. 30. Carpogonial branch initial. Fig. 31. Carpogonial branch. Figs. 32, 34. Developing cystocarps with young gonimoblast, fusion cell and involucral filaments. Fig. 33. Gonimoblast filament showing terminal carpospores.

The plant is diœcious.

The carpogonial branches are generally four-celled and are produced laterally (Text-Figs. 30, 31). These branches are 8–10·5 μ wide and the carpogonium is 7–9 μ broad. The first division of the fertilised carpogonium is transverse and only the upper daughter cell takes part in the formation of the gonimoblast filaments (Text-Figs. 29, 32, 34). The gonimoblast filaments are about 3 μ wide and form carpospores at the tips (Text-Fig. 33). The carpospores are 5-6 μ broad and 12–15 μ long.

A distinct fusion cell is formed (Text-Figs. 32, 34). The process of widening of the protoplasmic connections begins quite early (Text-Fig. 29). The supporting cell, the sterile cells of the carpogonial branch, and the lower daughter cell of the fertilized carpogonium all take part in the formation of the fusion cell.

The involucral filaments are very prominently developed (Text-Fig. 34). They are formed from the cells above and below the supporting cell and its adjacent cells (Text-Figs. 29, 32). These filaments are much branched and grow into a large envelope covering the gonimoblast filaments completely (Text-Fig. 34).

L. mucosa Howe

(Text-Figs. 35–50)

This alga was collected at North Bimini in the Bahamas by Dr. H. J. Humm who very kindly sent it on to us. It agrees very well with the description given by Howe (1920; see also Taylor, 1928).

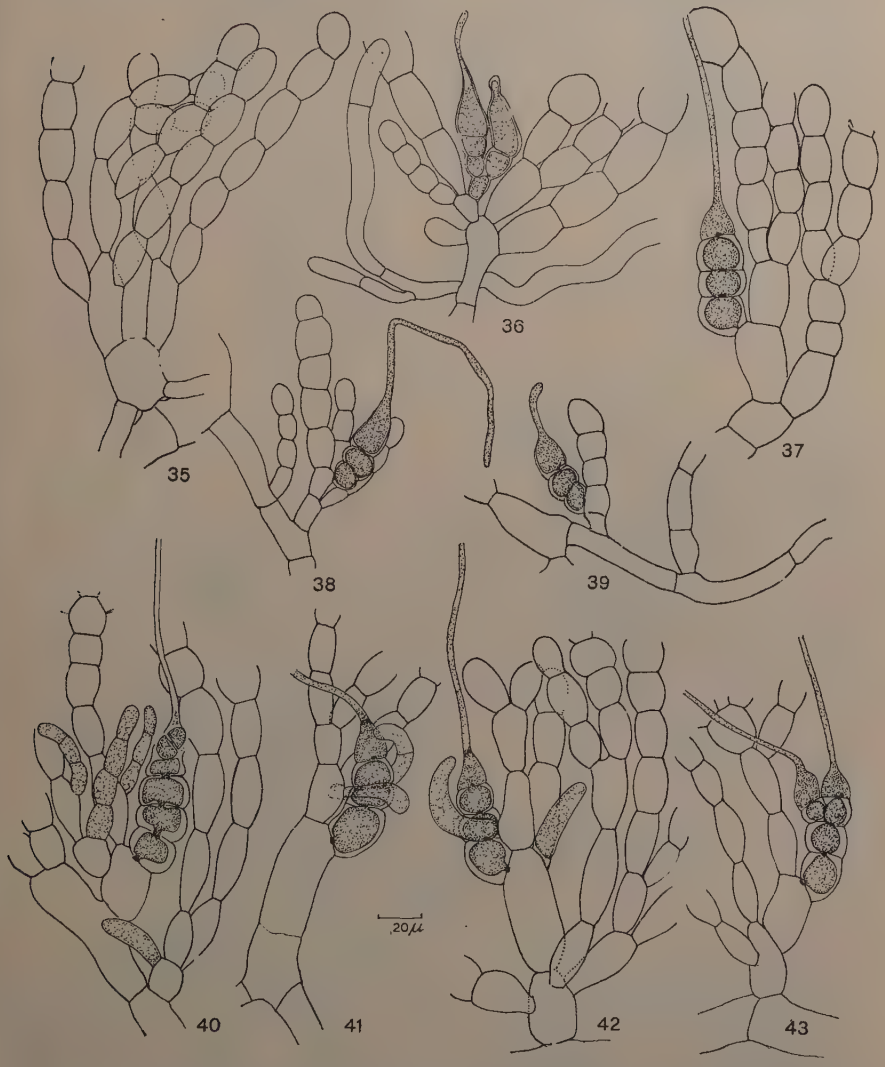
The thallus is highly mucilaginous and the branching monopodial. The assimilatory filaments are 4–5 times furcate (Text-Fig. 35). These are generally short and 30–40 μ wide in the lower parts and 25–35 μ wide above. The cells in the lower portions are up to 1½ times as long as broad and in the upper portions nearly isodiametric.

The alga is diœcious.

The carpogonial branches are not formed laterally but are formed by the modification of one of the furcations of the assimilatory filaments (Text-Figs. 36–39, 43). Usually only one of the arms of the furcation is replaced by a carpogonial branch, but sometimes both the arms may get modified into a pair of carpogonial branches (Text-Figs. 36, 47). The carpogonial branches are generally four-celled and have a long trichogyne (Text-Fig. 37).

The present alga showed a great variation in the number of cells in the carpogonial branches and in the mode of their formation. The alga has a number of rhizoids arising from the lower portions of the assimilatory filaments (Text-Figs. 38, 39). These in turn give rise to secondary assimilatory branches which have fewer furcations. The carpogonial branches formed by these secondary assimilatory filaments

are three-celled (Text-Figs. 38, 39). In some cases they are only two-celled, occupying a peculiar position and appearing as if they are formed on one of the sterile cells of the carpogonial branches (Text-Fig. 43). Whether these peculiar carpogonial branches are all fertile or abortive is very difficult to say. The carpogonial branches are 20–25 (—30) μ broad.



TEXT-FIGS. 35–43. *L. mucosa*. Fig. 35. Assimilatory filament. Figs. 36–39, 43. Carpogonial branches. Figs. 40, 42. Initiation of involucral filaments.

FIGS. 44–50

TEXT-FIGS. 44–50. *L. mucosa.* Figs. 44, 46, 49, 50. Post-fertilisation stages. Note the involucral branches and the nature of the cystocarp and also the descending rhizoid like filaments in Fig. 49. Fig. 47. Two carpogonial branches on the same supporting cell. Figs. 45, 48. Gonimoblast filaments with terminal carpospores.

After fertilisation the carpogonium cuts off the trichogyne and undergoes transverse division as in other species (Text-Figs. 41, 42). The upper daughter cell alone gives rise to a number of very short gonimoblast filaments (Text-Fig. 40). These gonimoblast filaments are 6–10 μ broad and form carpospores terminally. The carpospores are very large, measuring 28–38 $\times$ 14–18 μ. The carpospores are formed in large numbers and on discharge leave behind characteristically large hyaline balloon-shaped empty carposporangial walls which in aggregate give a cloud-like appearance to the cystocarp (Text-Figs. 44, 46, 49, 50). As already mentioned, the gonimoblast filaments are few-celled and do not form elongate branches (Text-Figs. 45, 48, 50).

The lower daughter cell of the fertilised carpogonium does not take part in gonimoblast formation. A conspicuous fusion cell is not seen, but protoplasmic connections in the carpogonial branch become slightly broader.

The cystocarps in the *Liagora* species belonging to the section Mucosæ have often been described as either nude or as having only a few rather inconspicuous involucral filaments. The writers have not seen any nude cystocarps in this species. Initiation of involucral filaments takes place immediately after fertilisation (Text-Figs. 40, 41, 42). These filaments are formed by the cells adjacent to the cells on which the carpogonial branch is placed. These filaments at first encircle the base of the carpogonial branch and produce a few branches (Text-Figs. 44, 46). A few descending filaments are also often produced by the cells giving rise to the involucral branches (Text-Figs. 49, 50). The involucral filaments never develop in any great quantity and are never seen to envelope the gonimoblast filaments. They merely coil round the sterile cells of the carpogonial branch so that these cells are often completely covered, while the gonimoblast filaments are fully exposed.

The details of post-fertilisation changes are very nearly the same as those given by Howe (1920). The formation of the involucral filaments has now been very clearly observed.

CONCLUSION

The present study of four species of *Liagora* has more or less confirmed the details known about them earlier. It has, in addition, supplied a few essential details with regard to the formation of the fusion cell and the involucral filaments. Together with the information known from the important contributions made by Boergesen (1915–20; 1927), Kylin (1930), Yamada (1938), Tseng (1941), Abbott, (1945), and Papenfuss (1946), it is now possible to summarise the post-fertilisation changes with a certain amount of definiteness.

Division of the fertilised carpogonium.—The fertilised carpogonium, in all the species, undergoes a transverse division. Out of the resulting two daughter cells, the upper one alone takes part in the formation of the gonimoblast filaments.

Fusion cell.—Subsequently, there is often observed in a number of species a widening of the protoplasmic connections between the different cells of the carpogonial branch and the supporting cell. In some cases, it goes further and a distinct fusion cell is formed. This aspect varies from species to species. In *L. maxima* and *L. erecta* for instance, the cross-walls of the carpogonial branch are completely obliterated and a large fusion cell including the supporting cell is formed; similarly also in *L. harveyiana*. In *L. papenfussii*, *L. viscida* and *L. ceranoides* various degrees of widening of the protoplasmic connections are noticed; so also in *L. mucosa*.

Involucral filaments.—In all species so far investigated, involucral filaments are definitely formed. These are formed only by the vegetative cells below and above the supporting cell and from the adjacent cells. It can be safely said that all reports of their formation from the sterile cells of the carpogonial branch or the supporting cells can be discounted.

The quantum of the involucral filaments formed differs from species to species. In some (*e.g.*, *L. mucosa*, *L. papenfussii*) they merely envelope the carpogonial branch and do not cover the gonimoblast. In others, they grow further but still do not completely envelope the gonimoblast filaments (*L. ceranoides*). In the rest, they are profusely formed and completely envelope the gonimoblast filaments which occupy a relatively small portion in the centre (*L. erecta*, *L. maxima*, *L. viscida*, *L. harveyiana*, etc.).

Yamada (1938) was the first to make a detailed study of *Liagora* spp. and attempt to analyse them, grouping them into definite sections. His system is now generally accepted.

L. mucosa, along with *L. mucosissima* Yamada, *L. pedicellata* Howe and *L. samænsis* Tseng, belongs to the section Mucosæ which is characterised by the carpogonial branches being modified assimilatory filaments. This is a very reliable character and in this respect the section is a well-defined and distinct one.

The other two sections of Yamada are Validæ and Farinosæ. The latter is characterised by capitate clusters of antheridia and cylindrical cells of the assimilatory filaments, as against unclustered antheridia and torulose cells in the former. These two sections are also very distinct. Many species of the Validæ have been studied and there is now need to study the species belonging to the Farinosæ. Desikachary (1956) studied *L. papenfussii* which, according to Abbott, belongs to this section. But this species does not have cylindrical cells in the assimilating filaments or capitate antheridial clusters as in the rest of the Farinosæ (see also Abbott, 1945). A study of more species belonging to the Farinosæ seems to be called for.

L. papenfussii and three other species produce tetraspores instead of carpospores and a transfer of the place of meiosis from the carpogonium to the carposporangium has been suggested in these cases. If that is the case, then these forms should be separated into a separate section, the Tetrasporiferæ. A good deal of significance is attached to the development of the tetraspores in the evolution of the diplobiont in the red algæ and the suggested separation of these forms is both on account of this importance and also the diploid nature of the gonimoblast filaments, *i.e.*, the carposporophyte.

The section Orientales was originally based on the very simple carpogonium and cystocarp in the single species placed here by Yamada. Since then, Yamada himself (Yamada, 1944) has transferred his *L. orientalis* (non *L. orientalis* J. Ag.) to the Acrochætiaceæ as a new genus, *Liagorophila*. In the same paper he discusses *L. formosona* described by him as a new species in 1938 and transfers it to *L. orientalis* J. Ag. which, according to him, belongs to the Mucosæ. In this species, the carpogonial branch is produced laterally and does not represent a modification of the assimilatory filament, as in the species belonging to the section Mucosæ mentioned earlier. Thus, it is different from other Mucosæ as typified by *L. mucosa* and there seems no justification for including it in that section. *L. orientalis* may, therefore, be transferred to the Validæ with whose species it agrees in general features. Thus, the necessity for a separate section Orientales to include this species no longer exists. According to the authors, therefore, the genus *Liagora* can be divided into: (1) Validæ, (2) Farinosæ, (3) Tetrasporiferæ and (4) Mucosæ, each one of these sections being sufficiently well defined and markedly different from the others.

The sections could be keyed out as follows:

1. Carpotetraspores present..... Tetrasporiferæ.
1. Carpotetraspores absent ..... 2.
2. Carpogonial branches modified assimilatory branches .....Mucosæ.
2. Carpogonial branches lateral .....3.
3. Antheridia in capitate clusters.....Farinosæ.
3. Antheridia not in capitate clusters ..... Validæ.

Summary

Post-fertilisation development in four species of *Liagora*, *L. viscida*, *L. ceranoides*, *L. harveyiana* and *L. mucosa*, are described in detail, particular attention being paid to two features, the development of a fusion cell and involucral filaments. Contrary to Kylin's previous report, involucral filaments are definitely formed in *L. viscida*. Involucral filaments are also formed in the other three species investigated

though the quantum varies. A clear fusion cell with the obliteration of cross-walls in the carpogonial branch is seen in *L. harveyiana*. In *L. viscida* and *L. ceranoides*, there is noticeable widening of the protoplasmic connections between the cells of the carpogonial branch and supporting cell. In *L. mucosa* also there is a similar widening of protoplasmic connections, but this is not very pronounced. General features of post-fertilisation development in the genus are discussed and it is suggested that the genus be divided into four sections: Mucosæ, Farinosæ, Tetrasporiferæ and Validæ. A key to the sections suggested is also given.

The writers are very grateful to Prof. G. F. Papenfuss and Dr. H. J. Humm for material and to the Trustees of the Nuffield Foundation for their generous Travel Grant for one of us (T. V. D.). They are also indebted to Prof. M. O. P. Iyengar and to Prof. T. S. Sadasivan for kind suggestions.

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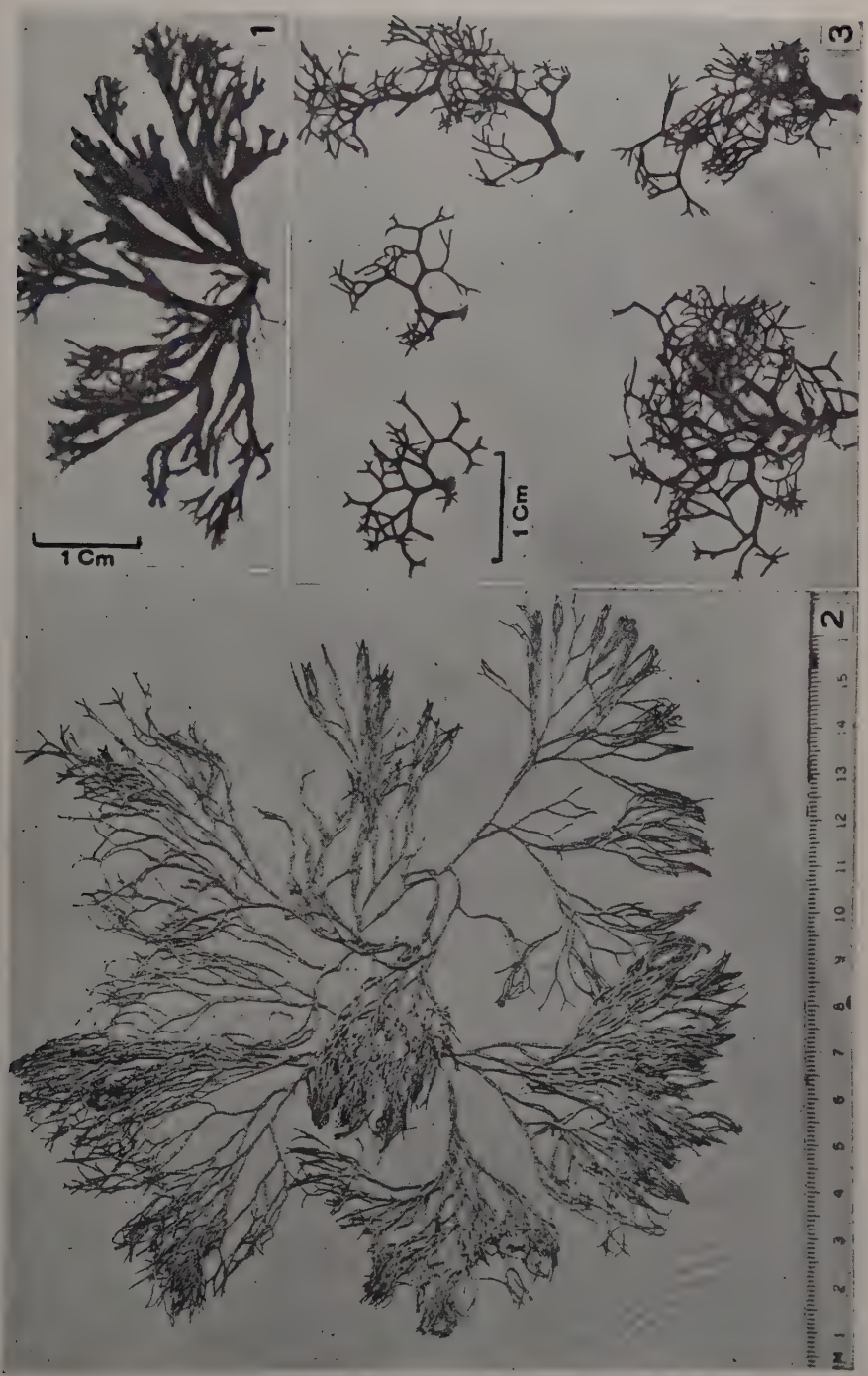

T. V. Desikachary & M. S. Balakrishnan

Explanation of Plate XVII

Fig. 1. *L. harveyiana.* Habit of a female plant.

Fig. 2. *L. ceranoides.* Habit of a female plant.

Fig. 3. *L. viscida.* Plants showing habit.

A LIST OF MARINE MYXOPHYCEAE FROM CAPE COMORIN (KANYA KUMARI), INDIA

By G. S. Venkataraman

Botany Division, Indian Agricultural Research Institute New Delhi-12

(Received for publication on May 25, 1957)

The present communication deals with some Myxophyceæ collected by the author from Cape Comorin (Kanya Kumari), the southernmost part of the Indian peninsula during June 1956.

1. *Glœothece vibrio* N. Carter. Geitler, *Cyanophyceæ* in Rabenhorst's *Kryptogamenflora*, 1932, Bd. XIV, 217, Fig. 104 *b*.

Cells 1·9–3·8 μ broad. On rocks along with other algæ.

2. *Aphanocapsa littoralis* Hansgirg. Geitler, *op. cit.*, 1932, 153, Fig. 66 *b*.

Cells 3·8–5·7 μ broad. On rocks along with other algæ.

3. *Entophysalis granulosa* Kützing. Geitler, *op. cit.*, 1932, 298, Fig. 146.

Cells 2·8–3·8 μ broad. On small pebbles and rocks.

4. *Xenococcus willei* Gardner. Geitler, *op. cit.*, 1932, 1168, Fig. 773.

Cells 3·8–13·3 μ broad; sporangium 15·2 μ broad. Epiphytic on *Lyngbya* sp.

5. *Myxosarcina concinna* Printz. Geitler, *op. cit.*, 1932, 325, Fig. 159.

Cells blue green, arranged regularly in tiers; endospores not seen; cells 1·9–5·7 μ broad and the colony 7·6–17·1 μ broad.

As far as the author is aware this is the first record of this genus in this country.

6. *Dermocarpa hemisphærica* Setchell and Gardner. Geitler, *op. cit.*, 1932, 391, Fig. 215.

Cells 9·5–13·4 μ broad. Epiphytic on *Lyngbya* sp.

7. *Oscillatoria nigro-viridis* Thwaites. Geitler, *op. cit.*, 1932, 943, Fig. 597 *c*.

Trichome 11·4 μ broad; cells 3·8–5·7 μ long. Free-floating.

8. *Oscillatoria sancta* Kütz (Gom.) Geitler, *op. cit.*, 1932, 943, Fig. 598.

Trichome 11·4 μ broad; cells 2·5–6·6 μ long. Free-floating.

9. *Oscillatoria salina* Biswas. Geitler, *op. cit.*, 932, 979, Fig. 624.

Trichome 5·7 μ broad; cells 1·9–3·8 μ long. Free-floating.

10. *Oscillatoria raciborskii* Wolosz. Geitler, *op. cit.*, 1932, 934, Fig. 618 *h*.

Trichome 8·9 μ broad; cells 1·9–3·8 μ long.

11. *Oscillatoria fracta* Carlson. Geitler, *op. cit.*, 1932, 946.

Trichome 7·6 μ broad; cells 1·9–7·8 μ long.

12. *Oscillatoria obscura* Brühl *et* Biswas. Geitler, *op. cit.*, 1932, 945.

Trichome 5·7 μ broad; cells 3·8–5·7 μ long. Free-floating.

13. *Lyngbya majuscula* Harvey. Geitler, *op. cit.*, 1932, 1060, Fig. 672 *c*, D.

Filaments 26·6–57·0 μ broad; cells 19·0–45·6 × 3·8–7·2 μ.

14. *Lyngbya semiplena* Ag. Geitler, *op. cit.*, 1932, 1061, Fig. 672 *a*.

Filaments 9·5–11·4 μ broad; free-floating.

15. *Microcoleus chthonoplastes* Thuret. Geitler, *op. cit.*, 1932, 1133, Fig. 739.

Filaments 19·0–34·2 μ broad; cells 3·8–13·3 μ × 9·5–11·4 μ.

16. *Schizothrix tenuis* Woronichin. Geitler, *op. cit.*, 1932, Bd. XIV, 1078.

Cells 1·9–3·8 μ × 1·9–3·8 μ.

17. *Calothrix pulvinata* Ag. Geitler, *op. cit.*, 1932, 600, Fig. 374 *e*.

Filaments 3·8–13·3 μ broad. Epiphytic on algæ.

18. *Calothrix crustacea* Thuret. Geitler, *op. cit.*, 1932, 601, Fig. 375 *b*.

Filaments 15·6–19·0 μ broad. Epiphytic on algæ.

19. *Brachytrichia balani* (Lloyd) Born. *et* Flah. Geitler, *op. cit.*, 1932, 554, Figs. 347, 348.

Trichomes 3·8–5·7 μ broad; heterocysts 6·6–11·4 μ broad. Growing gregariously on rocks with other algæ.

In conclusion, I am highly thankful to Dr. M. S. Randhawa for his keen interest and criticisms throughout this investigation. My thanks are also due to Dr. B. P. Pal and Dr. S. M. Sikka for their interest and for providing all the facilities.

Reference

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THE CLAVARIACEAE OF THE MUSSOORIE HILLS—VIII

By K. S. Thind and Sukh Dev

Botany Department, Panjab University, Amritsar

(Received for publication on March 14, 1957)

The first seven contributions (listed under references) describe 32 known Clavarias (mostly new records for India), 8 new species and 6 new varieties of Clavarias. This eighth contribution deals with 6 more known species (all new records for India) and 2 new varieties of Clavarias.

The classification of Corner, 1950, has been followed in this series.

The numbers of the species are the serial numbers of the Clavaroid flora of the Mussoorie Hills.

Type collections have been deposited in the Herbarium of the Panjab University. Duplicate material is at the Botany School, University of Cambridge, England.

47. *Ramaria subaurantiaca* Corner

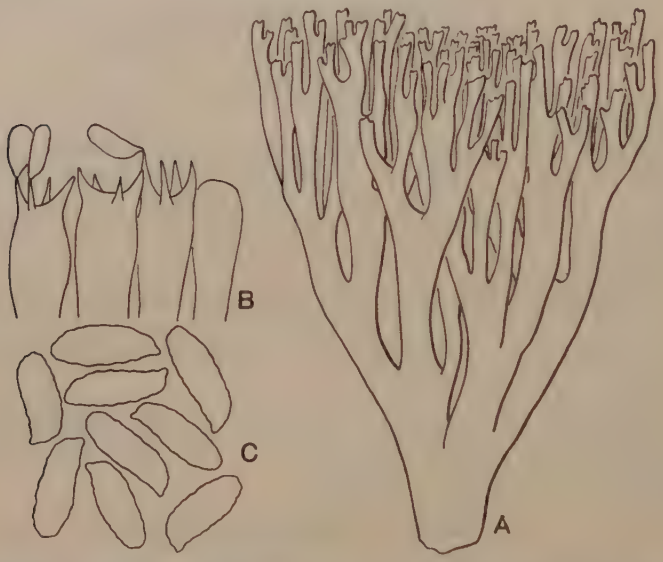
Fructifications up to 10 × 7 cm., scattered, erect, massive and medium-sized, radial, trunk absent, profusely branched, fleshy, smooth, glabrous, light orange yellow, branching polychotomous below but dichotomous above, rather short, massive, dense: primary branches massive, up to 8 mm. wide: ultimate branchlets very short to 1·5 mm. long, in pairs: apices blunt, lighter concolorous: flesh white, on bruising turning pale yellow: smell and taste inparticular. *Hymenium* spread all over, thickening, with numerous embedded spores, up to 98 μ thick. *Basidia* 5–8 μ wide, clavate: sterigmata 4, sometimes 2, 1·6–7 μ long. *Basidiospores* 8–14·4 × 3·2–4·8 μ, pale brown, wall dark, ellipsoid-enlogate, papillate, papilla small, less than 0·4 μ long, distinctly verruculose-rough, aguttate. *Hyphæ* monomitic, 2·5–16 μ wide, hyphal cells up to 140 μ long, hyaline, thin-walled, branched, inflated, septate, septa mostly at short intervals, sometimes slightly constricted at septa, clamps absent (Text-Fig. 1, A–C).

Collected on soil amid mosses, Sarkunda Temple, Mussoorie, September 12, 1954, 172.

This collection is identical with *Ramaria subaurantiaca* Corner (described by Balfour-Browne, 1955, from S.-E. Tibet) except that its spores are slightly longer than those of the latter. This is the second report of a *Ramaria* lacking clamps, the first report being that of *R. ignicolor* Bres. from Italy (see pp. 597–98 in Corner's Monograph).

48. *Ramaria obtusissima* (Pk.) Corner var. *gigantea* var. nov.

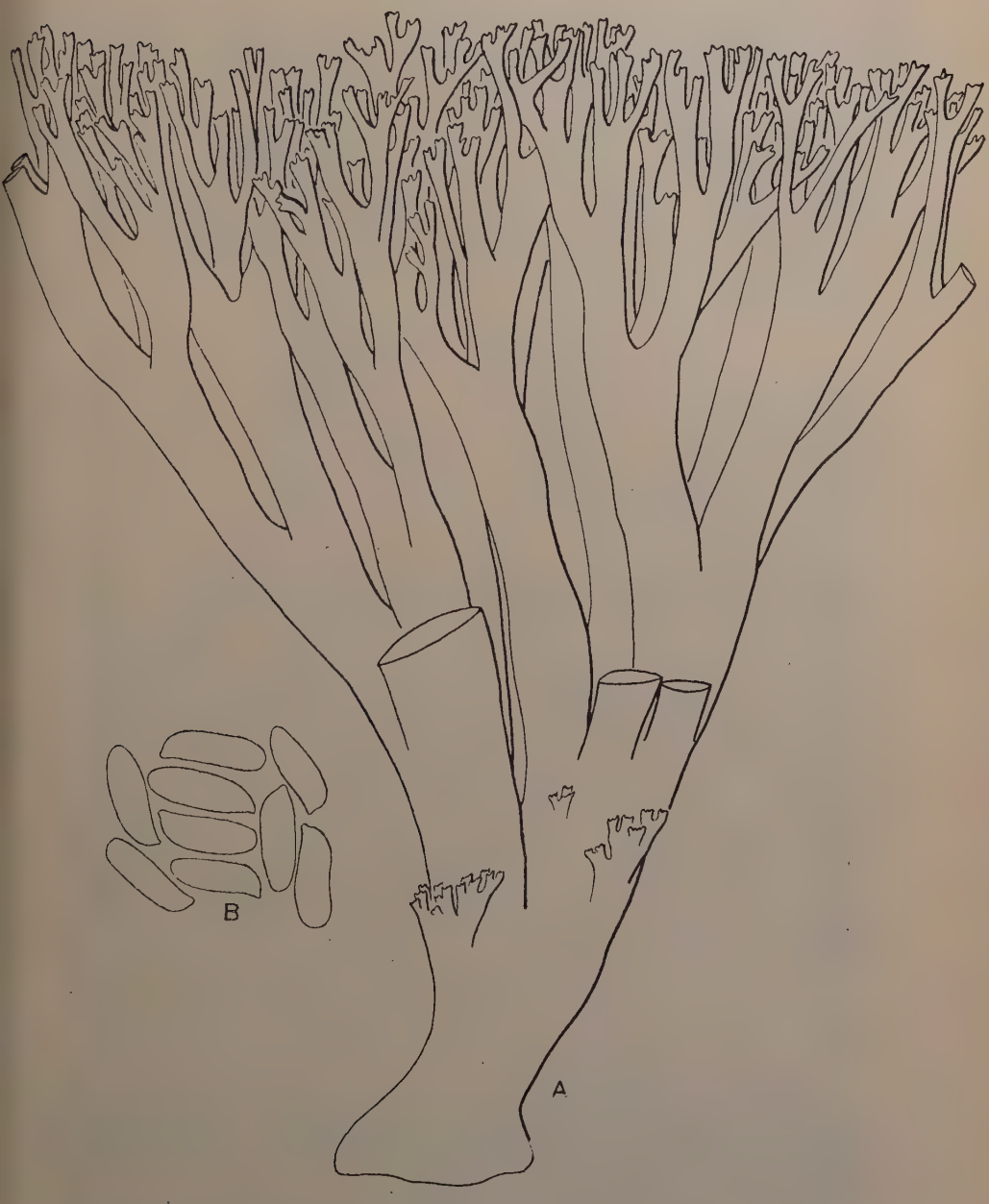
Usque 34 × 31 cm., solitaria, erecta, stipitata, valde ramosa, alba: and terram in silvis, Mussoorie (India).



Text-Fig. 1. *Ramaria subaurantiaca*, A. Fruit body, ×1. B. Basidia, ×1150. C. Verruculose basidiospores, × 1150.

Fructifications 34 × 31 cm., solitary, erect, very massive, very large-sized, radial, trunk present and base-like, profusely branched, fleshy, smooth, glabrous, white, on drying turning reddish brown: trunk stubby, massive, base-like, 5 × 3·5 cm., giving off very stout, massive, main branches near the ground level: branches polychotomous below, dichotomous above, unequal, irregular, internodes long: primary branches stout, up to 3·5 cm. wide: ultimate branchlets in pairs, usually small to 3 mm. long: apices blunt: flesh white, unchanging: smell and taste inparticular. *Hymenium* spread all over, thickening, with numerous embedded spores, up to 164 μ thick. *Basidia* 5–8 μ wide, clavate: sterigmata 4, straight or slightly incurved, 2–7 μ long. *Basidiospores* 10·4–14·4 × 3–4 μ, pale brown or ochraceous, wall dark, elongate-cylindric or narrowly ellipsoid-cylindric, papillate, papilla very small, smooth, not striated, aguttate. *Hyphæ* monomitic, 4–18 μ wide, hyphal cells up to 220 μ (or more) long, hyaline, thin-walled, branched, inflated, septate, septa at long intervals, clamped, clamps rare: a few narrow, uninflated, unseptate hyphæ, filled up with dense homogeneous oily substance. These hyphæ are 4–7 μ wide except at the swollen terminal ends where they enlarge up to 10 μ (Text-Fig. 2, A–B).

Collected on soil under Cedrus forest (*Cedrus deodara*) Dhanolti, Mussoorie, September 11, 1955, 173.



TEXT-FIG. 2. *Ramaria obtusissima* (Pk.) Corner var. *gigantea* var. nov. A. Large-sized fruit body, ×½. B. Smooth-walled basidiospores, ×1150.

This collection undoubtedly belongs to *Ramaria obtusissima* (Pk.) Corner. However, its size is considerably bigger being 34 × 31 cm. in contrast to 9–15 × 13 cm. reported for *R. obtusissima* (Corner, 1950, p. 609). The Mussoorie collection (n. 35) of *R. obtusissima*, "rough spored form" (Thind and Anand, 1956) is 14 × 11 cm. while Mussoorie collection (n. 70) of *R. obtusissima*, "smooth spored" (Thind and Dev, 1956) is 19 × 12 cm. Thus, the present collection (n. 173) is much larger than all the previous reports on the size of *R. obtusissima*. It may be desirable, therefore, to treat this collection as the large-sized variety (var. *gigantea* var. nov.) of the species *R. obtusissima*.

49. *Ramaria pusilla* (Pk.) Corner

Fructifications 2–6·5 × 0·8–3·5 cm., gregarious, solitary, not cæspitose, erect, small sized, radial, trunk present, rarely absent, sparsely to profusely branched, fleshy tough, smooth, glabrous, deep yellow, trunk and the lower parts of primary branches white, on drying turning brown: trunk up to 1·7 × 0·3 cm., white, radial, slender, arising from numerous brownish rhizomorphic strands at the base: rhizomorphs composed of monomitic, narrow, branched, clamped, thin-walled, pale brown, 2–4 μ wide hyphæ: branching dichotomous, or polychotomous below and dichotomous above, unequal, in alternating planes, internodes long: primary branches up to 3 mm. wide, long and raidal: ultimate branchlets very small, up to 2 mm. long, rarely up to 5 mm. long, mostly less than 1 mm.: apices sharply acute, concolorous, sterile: flesh white, turning red to dark red (vinaceous) on bruising or on long exposure: smell and taste inparticular. *Hymenium* spread all over except the sterile apices and white basal parts, not thickening, up to 60 μ thick. *Basidia* 4·4–6 μ wide, clavate: sterigmata 4, straight, 2·4–7 μ long. *Basidiospores* small, 4·8–7·2 × 2·4–3·2 μ, pale brown or ochraceous, ellipsoid to broadly ellipsoid or obovoid, papillate, papilla small, finely echinulate, aguttate. *Hyphæ* monomitic, 2·4–10 μ wide, up to 14 μ wide at the swollen portions, hyphal cells upto 270 μ long or even more, hyaline, thin-walled, branched, slightly inflated, septate, septa at long intervals, sometimes swollen terminally or at one side of the septum, clamped, clamps small to massive and common (Text-Fig. 3, A–C).

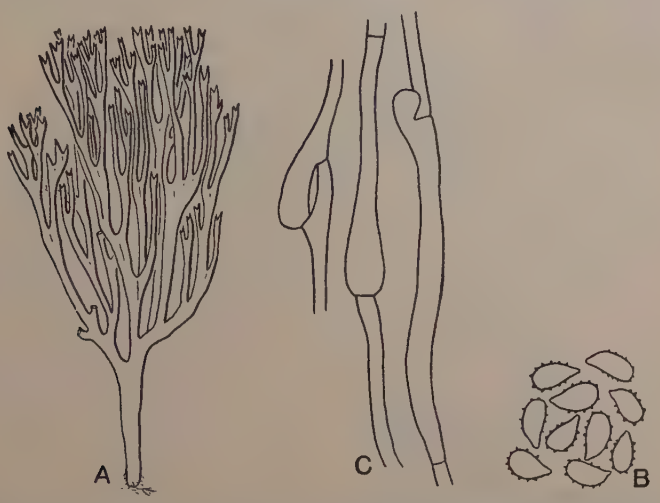
Collected on humicolous soil under Oak forest, The Park, Mussoorie, August 9, 1955, 174. On dead needles under *Cedrus* forest, Kodia, Mussoorie, September 12, 1955, 175.

These two collections come very close to *Ramaria pusilla* (Pk.) Corner. They also resemble *R. flaccida* (Fr.) Ricken which, however, has unchanging flesh. The collection n. 174 seems to come exactly between *R. pusilla* and its var. *australis* Coker in having the small size of the former and the colour of the latter.

50. *Ramaria sanguinea* (Coker) Corner

Fructifications up to 14·5 × 13 cm., scattered, erect, large sized, trunk absent but with a short thick white embedded base, profusely

branched, fleshy, smooth, glabrous, yellow, later turning light dark red at the top, on drying reddish brown to dark brown: branches



TEXT-FIG. 3. *Ramaria pusilla* (Pk.) Corner. A. Fruit body, ×1. B. Finely echinulate basidiospores, ×1150. C. Hyphæ with massive clamps, ×500.

polychotomous throughout, ultimate branchlets dichotomous, compact or crowded and looking like a cauliflower from the top, internodes medium-sized, radial, primary branches up to 9 mm. wide: ultimate branchlets very short to 2 mm. long: apices generally blunt or sometimes subacute: flesh white, on bruising slowly turning red to dark red: taste and smell inparticular. *Hymenium* spread all over, not thickening, up to 60 μ thick. *Basidia* 6–10 μ wide, clavate; sterigmata 4, straight, or slightly incurved, 1–8 μ long. *Basidiospores* 8·8–11·2 × 3·6–4 μ, pale brown, wall dark, narrowly ellipsoid or elongate, papillate, papilla up to 0·6 μ long, almost smooth, not striated, aguttate. *Hyphæ* monomitic, 3–15 μ wide, hyphal cells up to 154 μ long, hyaline thin-walled, branched, inflated, some narrow, uninflated, septate, narrow ones appearing unseptate, clamped. (Text-Fig. **4**, A–B).

Collected on moist soil, The Company Garden, Mussoorie, August 18, 1955, 176.

This collection fully fits in *Ramaria sanguinea* (Coker) Corner. In the yellow colour of the fruit bodies and reddening of the flesh this fungus resembles *Ramaria flava* (Fr.) Quél. (of Europe) which, however, has no clamps. In the present collection clamps are certainly present, yet many of the hyphæ of the medulla have septa without clamps. Thus it appears that this collection (n. 176) is linked up in some way with *R. flava*.

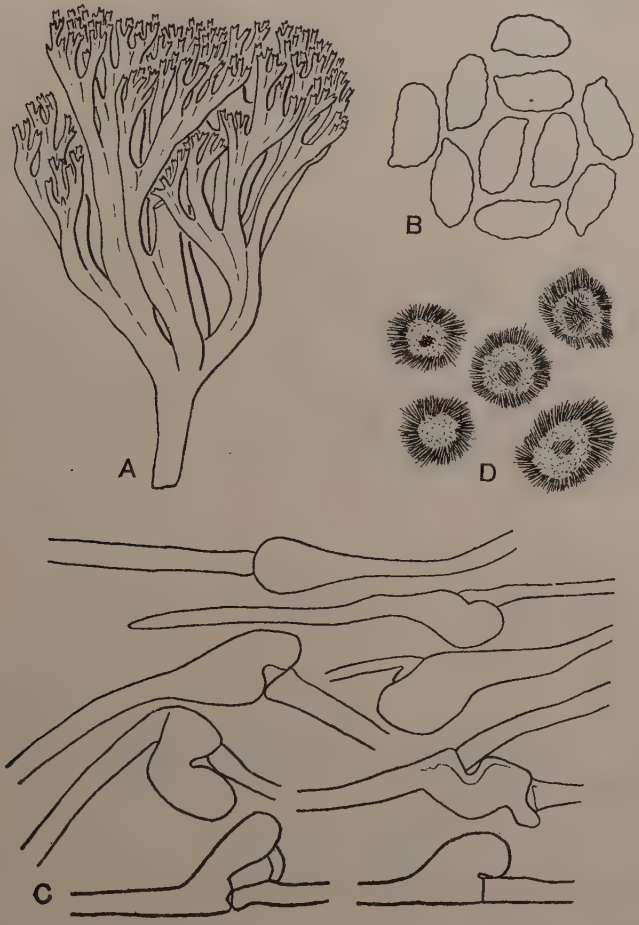
TEXT-FIG. 4. *Ramaria sanguinea* (Coker) Corner. A. Fruit body, ×½, B. Basidiospores, ×1150.

51. *Ramaria subgelatinosa* Corner

Fructifications up to 12·5 × 8·5 cm., gregarious, erect, large-sized, trunk present, profusely branched, fleshy, smooth, glabrous, light pinkish red with yellow tips, on drying becoming reddish brown or deep brown with a reddish tinge: trunk elongate, radial, up to 3·5 × 1·1 cm., dirty white, beset with abundant short hypha-like hairs, 2–3·8 μ wide and projecting up to 82 μ: branches polychotomous below but dichotomous above, longitudinally rugose especially below the branching, internodes long, shortening upward: primary branches up to 8 mm. wide, radial, stout, elongate: ultimate branchlets in pairs or singly, very short to 2 mm. long: apices blunt: flesh lighter concolorous, unchanging: smell and taste inparticular. *Hymenium* spread all over except the basal parts of the primary branches, not thickening or only slightly thickening, up to 80 μ wide. *Basidia* 48–60 × 8–10 μ, clavate: sterigmata 4, straight, stout, 2·4–10 μ long. *Basidiospores* 8–10·4 × 4·4–5·6 μ, pale brown, wall dark, ellipsoid, papillate, papilla up to 0·8 μ long, verruculose rough, aguttate. *Hyphæ* monomitic, 3–10 μ wide, up to 14 μ wide at the swollen parts, hyphal cells up to 284 μ long, hyaline, thin-walled, branched, inflated, septate, septa at long intervals, sometimes swollen on one side of the septum, clamped, clamps often variously swollen and of very irregular form, numerous extra-cellular crystals present in the context (Text-Fig. 5, A–D).

Collected on soil, Kadu Khal, Mussoorie, September 12, 1955, 177.

This collection resembles *Ramaria subgelatinosa* Corner except that it is not known whether the flesh was gelatinous or subgelatinous at the time of collection. The formalin-alcohol preserved specimens as well as dry specimens do not throw any light on this point. Its aguttate spores and presence of abundant crystalloid bodies in the flesh are other differences from the reported *R. subgelatinosa*. The



TEXT-FIG. 5. *Ramaria subgelatinosa* Corner. A. Fruit body, ×½. B. Verruculose basidiospores, ×1150. C. Hyphæ with variously swollen clamps of very irregular form, ×500. D. Extra-cellular crystalloid bodies from the context, ×500.

hyphæ in the Mussoorie collection are clamped but there are many septa in the longitudinal hyphæ of the medulla which have no clamps. On the other hand, many of the septa have variously swollen, or inflated, clamps of very irregular form.

52. *Ramaria mœlleriana* (Bres. *et* Roum.) Corner

Fructifications lignicolous, up to 3 × 2·6 cm., gregarious, cæspitose, erect, small-sized, radial, trunk absent or with a stubby and massive trunk-like base, sparsely branched, fleshy tough, smooth, glabrous, yellowish brown, arising from rhizomorphic strands: rhizomorphs up to 1 mm. wide, composed of narrow, highly or wholly thick-walled unseptate, 2–4 μ wide hyphæ: branches dichotomous, lax, up to 4 times: primary branches very massive, stubby, elongate, up to 5 mm. wide, radial: ultimate branchlets very small to 1 mm. long and 0·15–0·3 mm. wide, usually crowded, or in pairs, very short and nipple-like: apices blunt: flesh white: smell and taste inparticular. *Hymenium* spread all over, not thickening, up to 60 μ thick. *Basidia* 6–8μ wide, clavate: sterigmata 4, straight, 3–6·2 μ long. *Basidiospores* 6·4–7·2 × 3·2–4 μ, ochraceous or pale brown, wall dark, short, ellipsoid, papillate, papilla up to 0·5 μ long, verruculose (without distinct warts), aguttate. *Hyphæ* monomitic, 2–7·2 μ wide, up to 12 μ at the swollen regions, hyphal cells up to 172 μ (or more) long, hyaline, slightly to moderately thick-walled, up to 1 μ thick, highly convoluted, uninflated, narrow, branched, septate, septa at long intervals, sometimes swollen terminally or at one side of the septum, clamped, clamps common (Plate XVIII, Fig. 1; Text-Fig. 6, A–B).

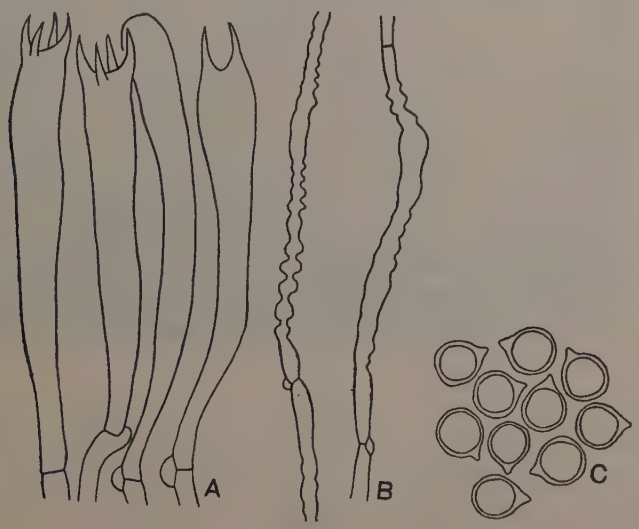
TEXT-FIG. 6. *Ramaria mœlleriana* (Bres. *et* Roum.) Corner. A. Verruculose basidiospores, ×1150. B. Clamped and slightly thick-walled hyphæ, sometimes swollen terminally, ×500.

Collected on dead wood, The Park, Mussoorie, August 20, 1954, 178.

This species is characterized by yellowish brown small but stubby fruit bodies arising from thick rhizomorphs, blunt apices, short ellipsoid and verruculose spores and highly convoluted thick-walled clamped hyphæ. It is very close to *Ramaria stricta* var. *concolor* Corner but is smaller, more of a tropical fungus, and with more rugulose and generally smaller spores.

53. *Clavulinopsis dichotoma* (God.) Corner

Fructifications up to 9 cm. tall, cæspitose clusters up to 3 cm. wide, individual fruit bodies up to 2·2 cm. wide, gregarious, scattered, usually cæspitose, of 2–6 fruit bodies, sometimes solitary, erect, medium-sized, radial to flattened, sparsely branched, trunk present, fleshy, smooth, glabrous, white, sometimes with a yellow tinge in the upper part: trunk up to 2 cm. × 3 mm., radial to flattened, white tomentose at the base: branches sparse, lax, 2–4 times, dichotomous, unequal, in alternating planes, elongate (*i.e.*, internodes long) usually divaricate: primary branches flattened, grooved (with one longitudinal groove along the mid-line), up to 3 mm. wide, divaricate; ultimate branchlets in unequal pairs, usually divaricate, up to 1·5 cm. long: apices subacute to blunt, sterile: flesh white; taste and smell inparticular. *Hymenium* spread all over except the tomentose base of the trunk, thickening, up to 86 μ thick. *Basidia* 40–56 × 5–8 μ, clavate, clamped at the base: sterigmata 4, sometimes 2, slightly incurved, long, slender, 5–10 μ long. *Basidiospores* 5·5–6·8 μ in diameter, hyaline, globose, papillate, papilla prominent and fine, up to 1·3 μ long, smooth, thin-walled, uniguttate, guttule large and filling almost whole of the spore cavity. *Hyphæ* monomitic, 1·7–8·6 μ wide, hyphal cells up to 223 μ (or more) long, hyaline, thin-walled, branched, uninflated, convoluted, slightly to prominently and deeply wavy so as to impart a beaded appearance to the hyphæ, septate, septa at long intervals, clamped, clamps common but not at all septa, H-connections present (Plate XVIII, Fig. 2; Text-Fig. 7, A–C).



TEXT-FIG. 7. *Clavulinopsis dichotoma* (God.) Corner. A. Basidia clamped at the base, ×1150. B. Basidiospores with a prominent papilla, ×1150. C. Highly wavy to beaded, clamped hyphæ, ×500.

Collected on humicolous soil, The Park, Mussoorie, August 8, 1954, 179.

This fungus belongs to *Clavulinopsis dichotoma* (God.) Corner and is recognized by the white, cæspitose, dichotomously branched fruit bodies, globose, uniguttate spores, and clamped hyphæ. The beaded or highly wavy feature of the hyphæ is very conspicuous in the Mussoorie collection.

54. *Clavulinopsis pulchra* (Pk.) Corner var. *coccinea* var. nov.

Usque 10 cm., alta, cæspitosa, stipitata, simplicia, erecta, coccineus: ad humum in silvis, Mussoorie (India).

Fructifications gregarious, solitary, cæspitose, cæspitose clusters with 2–12 fruit bodies, erect, medium-sized, trunk present, simple, rarely once or twice forked, fleshy, smooth, glabrous, red to deep red, sometimes paler coloured and yellow to orange (apices dark violet to black?), 1·5–10 cm. tall, cæspitose clusters up to 1·5 cm. broad, individual clubs 0·5–2 cm. wide or flattened to 5 mm.: trunk 4–15 ×0·5–1·5 mm. up to 3 mm. wide in the case of old flattened fruit bodies: clubs cylindrical, radial, becoming longitudinally furrowed or channelled with age, erect, often twisted, hollow to solid, rarely 1–2 times branched or forked: apices subacute to blunt or obtuse, fertile: flesh lighter concolorous, unchanging: smell and taste inparticular. *Hymenium* spread all over except the trunk, not thickening, up to 64 μ wide. *Basidia* 24–36 × 4–6 μ, clavate, filled with red granular contents: sterigmata 4, straight, 4–7·6 μ long. *Basidiospores* 5·2–6·4 × 4–4·8 μ, hyaline, broadly ellipsoid, papillate, papilla prominent, eccentric, up to 1·5 μ long, smooth, aguttate. *Hyphæ* monomitic, 2–10 μ wide, hyphal cells usually 30–60 μ long, sometimes up to 160 μ long, hyaline, thin-walled, branched, slightly inflated, septate, septa at short to long intervals, sometimes broader hyphæ constricted at septa, clamped, clamps common (Text-Fig. 8, A–B).

TEXT-FIG. 8. *Clavulinopsis pulchra* (Pk.) Corner var. *coccinea* var. nov. A. Fructifications, ×½. B. Broadly ellipsoid basidiospores with a prominent and eccentric apiculus, ×1150.

K. S. Thind & Sukh Dev

Collected on humicolous soil under Oak forest, Chakrata Toll, Mussoorie, August 30, 1954, 180.

This fungus has broadly ellipsoid spores with a very prominent apiculus and this is the spore character of *Clavulinopsis pulchra* (Pk.) Corner. *C. pulchra*, however, possesses predominantly yellow to deep yellow fruit bodies but the colour of the Mussoorie collection is predominantly red to deep red. Therefore, this Mussoorie collection (n. 180) is made a new variety of *C. pulchra* and is named *coccinea* in contrast to the forma *coccineo-basalis* already reported for this species which is more or less intensely scarlet at the base only.

This fungus is very close to *Clavulinopsis aurantio-cinnabarina* (Schw.) Corner, the spore of which, however, is subglobose with a relatively small apiculus. It is now felt that the previously reported *Clavulinopsis aurantio-cinnabarina* (Schw.) Corner from the Mussoorie hills (Thind and Anand: *J. Indian bot. Soc.*, **35**: 176–77, 1956) which possesses deep orange red fruit bodies and broadly ellipsoid spores with prominent apiculus (1 – 2 μ long) also belongs here and in future would be referred to *C. pulchra* var. *coccinea* var. nov.

Acknowledgments

The authors are deeply indebted to Mr. E. J. H. Corner, F.R.S., of the Botany School, Cambridge, England, for help in the identification of the species and valuable suggestions and Prof. P. N. Mehra, Head of the Panjab University Botany Department, for providing facilities and encouragement.

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Explanation of Plate XVIII

Fig. 1. *Ramaria mœlleriana* (Bres. *et* Roum.) Corner.

Fig. 2. *Clavulinopsis dichotoma* (God.) Corner.

FUNGI ISOLATED FROM RHIZOSPHERE—III*

By V. Agnihothrudu**

University Botany Laboratory, Madras-5

(Received for publication on August 13, 1957)

In this brief paper are enumerated thirteen species of Mucorales which the writer had isolated during his studies on the rhizosphere microflora of pigeon pea [*Cajanus cajan* (L.) Millsp.] in relation to the wilt caused by *Fusarium udum* Butler. Of these *Mucor jansseni* Lendner, *Mucor spinescens* Lendner and *Cœmansia reversa* van Tieghem and Le Monnier are reported for the first time from India.

7. *Rhizopus arrhizus* Fischer in Rabenhorst's *Kryptogamenflora*, 1892, **4**, 161; Saccardo, *Syll. Fung.*, 1888, **7**, 186; Mundkur, B. B., *Monogr. Coun. agric. Res. India*, 1938, **12**, 11; Subramanian, C. V., *J. Madras Univ.*, 1952, **22 B**, 208.

8. *Rhizopus nodosus* Namyslowski in *Bull. Acad. Sci., Carcovie*, 1910, B, 438; Saccardo, *Syll. Fung.*, 1888, **7**, 212; Mundkur, B. B., *Monogr. Coun. agric. Res. India*, 1938, **12**, 11; Subramanian, C. V. and Ramakrishnan, K., *J. Madras Univ.*, 1956, **26 B**, 370.

9. *Absidia spinosa* Lendner in *Bull. Herb. Boissier*, 1907, **7**, 250; Saccardo, *Syll. Fung.*, 1921, **21**, 824; Subramanian, C. V. and Ramakrishnan, K., *J. Madras Univ.*, 1956, **26 B**, 331.

10. *Mucor jansseni* Lendner in *Bull. Herb. Boissier*, 1905, **7**, 238; Naumov, N. A., *Clés des Mucorinées*, 1939, 37; Gilman, J. C., *A Manual of Soil Fungi*, 1945, 29.

Cultures fast growing on potato dextrose and Czapek (Dox) agar with white, fluffy, cottony aerial mycelium turning gradually greyish-black with the abundant production of sporangia. Sporangiophores branched in an irregular cymose pattern with distinctly discernible longitudinal striations on the wall. These striations are very clear in dry mounts of the fungus. Sporangia varying in diameter from 25 to 85 μ. Columella spherical to oval with a distinct collarette at the base, measuring 13 to 34 μ by 10 to 27 μ, greyish in colour, sporangial wall fragile. Spores spherical, 3·2 to 5·2 μ in diameter, mostly 4·8 μ (Fig. 1).

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* Formed a part of the thesis approved for the Ph.D. Degree of the University of Madras.

"Fungi Isolated from Rhizosphere," I and II appeared in the *Proc. Indian Acad. Sci.*, 1955, **43 B**, 98–104 and *J. Indian bot. Soc.*, 1956, **35**, 38–42 respectively.

** Present Address: Department of Mycology, Tocklai Experimental Station, Indian Tea Association, Cinnamara, Assam.

11. *Mucor racemosus* Fresenius in *Beiträge zur Mykologie*, Frankfurt, 1850, 12; Saccardo, *Syll. Fung.*, 1888, **7**, 192; Butler, E. J. and Bisby, G. R., *Monogr. Coun. agric. Res. India*, 1931, **1**, 8; Subramanian, C. V., *J. Madras Univ.*, 1952, **22 B**, 208.

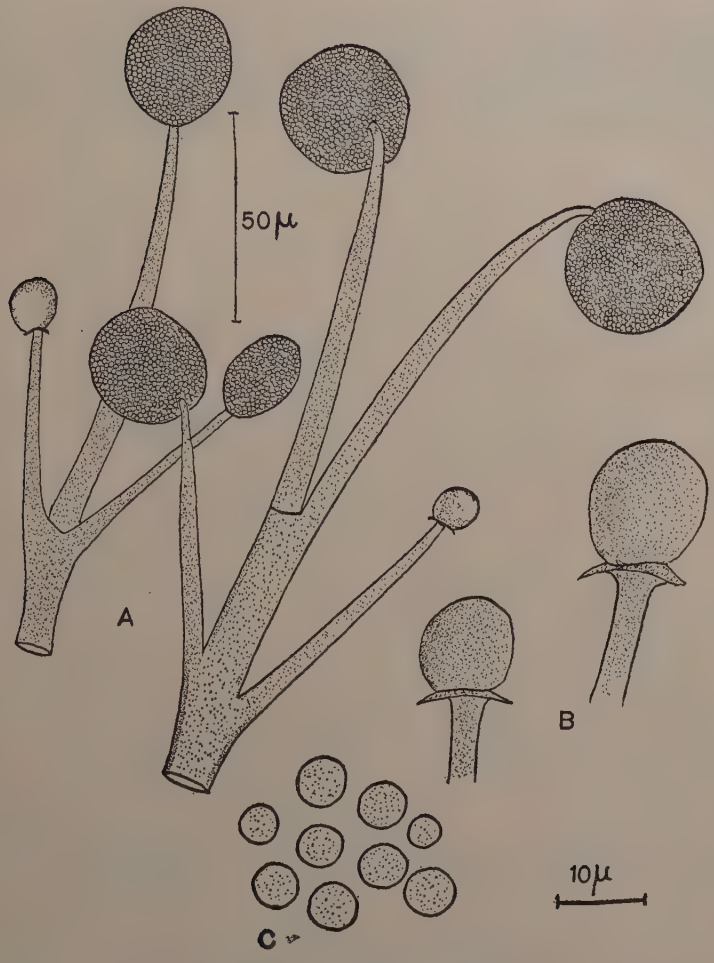

FIG. 1. *Mucor jansseni* Lendner

A. Sporangiophores and sporangia. B. Columellæ. C. Spores.

12. *Mucor spinescens* Lendner in *Bull. Herb. Boissier*, 1908, **8**, 79; Graf, P. W., *Mycologia*, 1928, **20**, 176; Naumov, N. A., *Clés des Mucorinées*, 1939, 39, as *Mucor plumbeus* Bonorden var. *spinescens* (Lendner) Naumov; Gilman, J. C., *A Manual of Soil Fungi*, 1945, 176.

Turf white in colour, turning gradually grey in centre of the colony first and later peripherally, up to 5 mm. in height, collapsing with the aging of the culture. Sporangiophores up to 2 mm. high and 6 to 10 μ in width. Branching of the sporangiophores is in an irregular cymose pattern. Sporangiophores often somewhat constricted at the base of the sporangium and slightly incurved. Sporangia spherical, subspherical or globose, varying in diameter from 48 to 68 μ, mostly hyaline, rarely subhyaline. Columella short, smooth, slightly conical, surmounted by a short, blunt or pointed process. Spores numerous, spherical to globose 6·4 to 8·0 μ (mostly 7·2 μ), hyaline to subhylaine (Fig. 2).

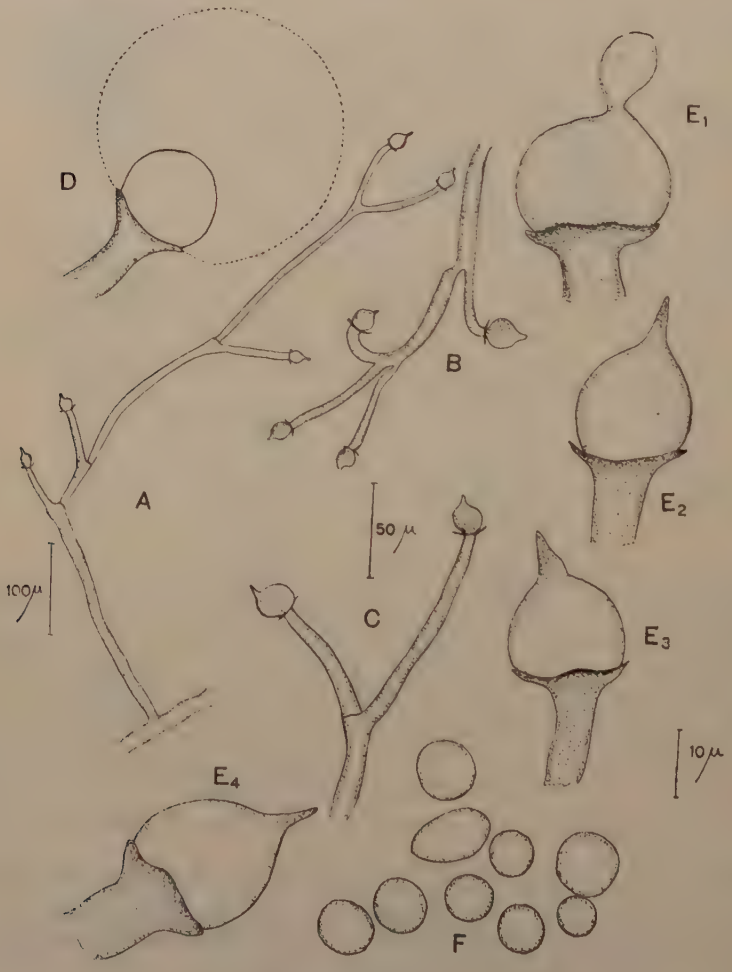

FIG. 2

FIG. 2. *Mucor spinescens* Lendner

A–C. Branched sporangiophores of an irregular racemose type. D. An atypical columella. E_1–E_4. Columellæ with spinescent projections. F. Sporangiospores.

13. *Circinella muscæ* (Sorokine) Berlese and de Toni in Saccardo, *Syll. Fung.*, 1888, **7**, 216; as *Circinella spinosa* van Tieghem and Le Monnier, Mundkur, B. B., in *Monogr. Coun. agric. Res. India*, 1938, **12**, 11; as *Circinella muscæ* (Sorokine) Berlese and de Toni, Subramanian, C. V. and Ramakrishnan, K., *J. Madras Univ.*, 1956, **26 B**, 342.

14. *Choanephora cucurbitarum* (Berk, and Rav.) Thaxter in *Rhodora*, 1903, **15**, 97–102; Saccardo, *Syll. Fung.*, 1905, **17**, 507; Butler, E. J. and Bisby, G. R., *Monogr. Coun. agric. Res. India*, 1931, **1**, 8.

15. *Cunninghamella echinulata* Thaxter in *Rhodora*, 1903, **5**, 508; Saccardo, *Syll. Fung.*, 1905, **17**, 508; Mundkur, B. B., *Monogr. Coun. agric. Res. India*, 1938, **12** 10; Subramanian, C. V., *J. Madras Univ.*, 1952, **22 B**, 208.

16. *Cunninghamella bertholletiæ* Stadel in *Mykol. Zbl.*, 1912, **1**, 218–19; Ramakrishnan, K., *Proc. Indian Acad. Sci.*, 1955, **42 B**, 112; Subramanian, C. V. and Ramakrishnan, K., *J. Madras Univ.*, 1956, **26 B**, 344.

17. *Syncephalastrum racemosum* (Cohn) Schroeter in Cohn's *Kryptogamenflora von Schlesien*, 1889, 615; Saccardo, *Syll. Fung.*, 1888, **7**, 232; Ramakrishnan, K. and Subramanian, C. V., *J. Madras Univ.*, 1952, **22 B**, 46.

18. *Syncephalis cornu* van Tieghem and Le Monnier in *Ann. Sci. nat.*, 1873, **17**, 376; Saccardo, *Syll. Fung.*, **7**; Ramakrishnan, K., *Proc. Indian Acad. Sci.*, 1955, **42 B**, 112; Subramanian, C. V. and Ramakrishnan, K., *J. Madras Univ.*, 1956, **26 B**, 374.

19. *Cœmansia reversa* van Tieghem and Le Monnier in *Ann. Sci. nat.*, 1873, **17**, 392; Gilman, J. C., *A Manual of Soil Fungi*, 1945, 60; Farrow, W. M., *Mycologia*, 1954, **46**, 643.

Turf pale yellow, slow growing, substrate mycelium repent, branched and septate. Sporangia absent, conidiophores dichotomously branched bearing sporocladia; sporocladia somewhat inflated, septate, often tapering to 1 or 3 terminal cells and bearing phialides on the lower aspect. Sporocladia measuring 16 to 24 μ by 4 to 7 μ, phialides short, one-celled, ovoid to elongate, ellipsoid, measuring 2·4 to 3·2 μ by 1·6 to 2·4 μ, conidia borne at the end of the phialides, one-celled, hyaline, smooth-walled, elliptic to fusiform, 4·8 to 8·0 μ by 1·6 to 2·8 μ (Fig. 3). This form is comparatively rare in the rhizosphere and control soils. It was recorded only twice from rhizosphere.

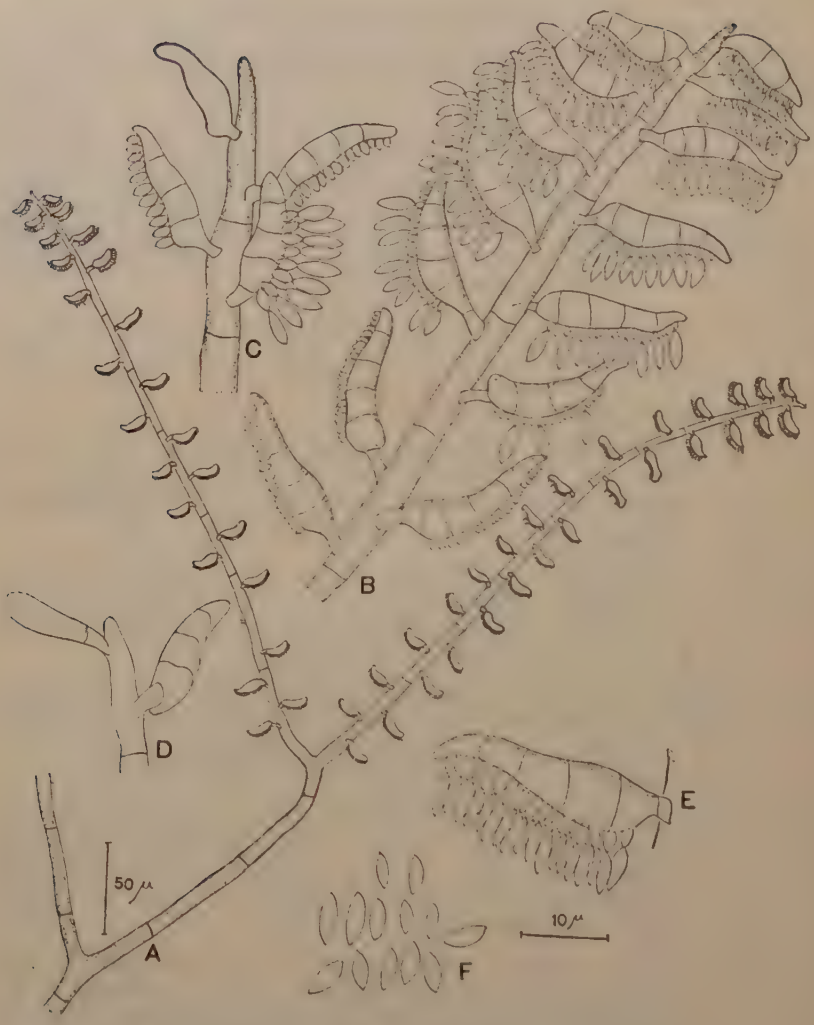

FIG. 3. *Cæmansia reversa* van Tieghem and Le Monnier

A. Dichotomously branched conidiophore. B–D. Enlarged fertile part of the conidiophore showing the sporocladia. E. Sporocladium bearing phialides and Conidia. F. Conidia.

ACKNOWLEDGEMENTS

I am much thankful to Professor Dr. T. S. Sadasivan and Dr. C. V. Subramanian of the University Botany Laboratory, Madras, for their valuable suggestions and criticism. I am also grateful to the University of Madras for the award of a research studentship during the tenure of which this work was done.

STUDIES IN PTERIDOPHYTES

I. The Shoot Apex of *Isoetes coromandeliana* L.*

By S. Bhambie

School of Plant Morphology, Meerut

(Received for publication on June 28, 1957)

Shoot apex in vascular plants is a unique structure inasmuch as it is endowed with the power of unlimited growth. For this reason its structure and organization have ever been an interesting field of enquiry (see reviews by Foster, 1939, 1941 *a*; Sifton, 1944; Philipson, 1949; Esau, 1950; Johnson, 1951; Wardlaw, 1951, 1953; Gifford, 1954; Puri, 1955). At one time it was believed that the shoot apex of lower vascular plants, the pteridophytes, grows, in general, by a single apical cell. But recent work has shown that the organization of shoot apex in these plants also is no less variable than that in the angiosperms. In fact a single apical cell exists only in a few cases like *Equisetum*, *Dryopteris*, *Cyathea* and in some other members of Filicineæ, while in others and in the so-called fern " allies " the structure is more or less complex.

The curious *Isætes*, which has sometimes been likened to *Echidna* of zoologists, has many points in its anatomy and morphology about which we do not have quite clear ideas. For instance, we lack exact information about the nature of apical growth, leaf initiation, secondary growth, rhizomorphic stele, etc. In the present investigation, attention is focussed on the first of these problems, that is, the structure and organization of the shoot apex.

Material and Methods

The material of *Isætes coromandeliana* L. and *I. engelmanni* A. Br. has been used for this investigation. *I. coromandeliana* has been reported growing wild at a number of places in India, *e.g.*, Coromandel Coast (Pfeiffer, 1922), Bombay (Mac Cann, 1934), Banaras (Bharadwaja, 1935), and Baroda (Gaekwad & Deshmukh, 1956) from where a new variety has been described. Some years ago this species was discovered growing wild in an extensive patch about 4 miles north of Meerut, though this has not so far been reported in press. Under the impact of " grow more food campaign " launched by the owner of the land the patch is being gradually reduced and the number of plants that appear from June to November every year has now become very small. Our apprehension is that the plant may disappear completely from this locality, in course of time, unless some immediate steps are taken to preserve it.

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* Research contribution No. 10 from the School of Plant Morphology, Meerut College, Meerut.

Curiously enough all the material examined by the author so far has turned out to be megasporophyllous, no microsporophylls having been discovered in any of the plants. However, I had occasion to examine a slide of Professor P. Maheshwari showing a few microsporophylls being surrounded by megasporophylls. This preparation, however, was of Madras material.

A large number of plants of this species in various stages of development were collected and fixed in F.A.A. at weekly intervals. Some of them were also fixed in Randolph's modified Navaschin fluid and also in absolute alcohol and acetic acid (3 : 1) between 9 a.m. and 1 p.m. Alcohol preserved material of *I. engelmanni* was brought by Prof. V. Puri from Ithaca, N.Y., in 1950 and was very kindly passed on to the author for investigation.

The material of the axis, after removing the outer leaves, sporophylls, roots and also in most cases the lower portion of the axis itself, *i.e.*, the rhizomorphic stele, was prepared for microtomy following the customary technique. Sections were cut between 6 to 14 microns thick and stained either with Iron-alum Hæmotoxylin, or Crystal-violet Erythrosin. Iodine was used for testing starch grains and Sudan IV, for cuticle in leaves and apex.

Historical

Morphological and anatomical studies of *Isætes* were started about the middle of the last century, the earliest work being that of Von Mohl (1840) who gave attention to the arrangement of roots and mode of secondary thickening, etc. It was, however, Hofmeister (1862), who gave a more or less complete description of the development and anatomy of the plant. He was led to believe that there existed at the shoot apex of this plant a single apical cell whose mode of growth was also described.

Hegelmaier (1874, quoted from West and Takeda, 1915) is said to have suggested, the occurrence, in *I. velata* and *I. duriæi* of an actual apical cell surface which is extended all over the stem apex. He further recognized some cells just beneath the extreme apex of this surface layer which were alleged to make up the woody mass of the stele in the later stages of development and which were accordingly designated as pleurome initials. Bruchmann (1874, quoted from West and Takeda, 1915) also is reported to have to come to an almost similar conclusion. He, however, envisaged in *I. lacustris* a smaller layer of initials, only those confined to the uppermost part of the stem apex. These cells by further divisions were believed to give rise to a group of meristematic cells that formed the vascular tissue as well as a portion of the cortex. It is apparent from the pioneer works of both these eminent authors that they stipulated the occurrence of a more or less extensive apical cell surface in the species studied rather than a single apical cell.

De Bary (1884) pointed out that the organization of shoot apex in *Isætes*, *Selaginella* and some Marattiaceæ forms a transitional

stage between a structure with a single apical cell and an apex with a well differentiated meristem. He suggested that in these cases "the entire meristem of the apex originates from one single common initial, which is called from its position at the apex of stem and root, the apical cell. Successive bipartitions divide the apical cell in each case into an apical part, which retains the original position and form, this being compensated again by growth, and remains as the apical cell, and a basal interior part, which is added to the growing meristem" (De Bary, 1884, p. 15).

Farmer (1890), following Hegelmaier, conceived of a columnar layer of meristematic cells on the apex dividing anticlinally and rarely periclinally. Van Tieghem (1891), on the other hand, advocated the occurrence of a single apical cell. It is surprising that Campbell (1891, 1918 and 1940) who made a very detailed study of *Isœtes* did not pay any attention to this problem. In 1891, while describing the development of a young sporophyte of *I. echinospora*, he just referred to the growing point of the stem as "nearly a flat area" (Campbell, 1891, p. 249).

Scott and Hill (1900) maintained the existence of a single apical cell and observed it in transverse as well as in longitudinal sections. Smith in the same year, however, discarded such a hypothesis and instead of it suggested a group of initial cells. He wrote, "the superficial layer appears to divide only in anticlinal direction except when young leaves are about to be formed but this layer as Hegelmaier showed, can on no account be regarded as dermatogen" (Smith, 1900, p. 288). He was the first person to point out that a group of initial cells function in the stem apex of *Isœtes* and that there was no apical cell surface as was proposed by earlier workers.

West and Takeda (1915) who have made a very exhaustive study of some species of *Isœtes*, especially *I. japonica*, have supported the inference of Smith (1900) that there is a conical mass of meristematic tissue, the outer layer of which divides anticlinally and rarely periclinally, while the internal cells divide irregularly in both the planes. In the same year Lang (1915 *b*) also observed a group of initials forming the apex of *I. lacustris* but he did not completely exclude the probability of there being a single initial cell in some cases. Recently G. M. Smith (1938, 1954) has accepted the concept of an apical meristem consisting of a group of initial cells.

La Motte (1933, 1937 *a*, 1937 *b*) has devoted considerable attention to studying the conditions affecting the development of megagametophyte and embryo sporophyte. His investigations are indeed valuable, but regarding the shoot apex of young sporophyte he only points out the absence of an apical cell. The dermatogen according to him becomes a definite tissue during seventy to seventy-six hours after germination.

Wardlaw also has contributed a series of valuable papers during the last three decades on the development of shoot apex of different

Pteridophytes. On the basis of structural patterns of the shoot apex, he distinguishes the plant kingdom into seven possible groups ranging from single apical cell to a complicated zonal structure of angiosperms (Wardlaw, 1951 and 1953). He also finds a group of initials in *Lycopodium* and *Selaginella* but he has laid more stress on the physiological, genetical and biochemical aspects of the cells rather than on their morphological and anatomical characters. According to him the histological organization of the shoot apex is largely conditioned by the size, shape and general metabolism of the meristematic cells.

Thus there is some difference of opinion as to the organization of the shoot apex in *Isœtes*, but majority of the workers in recent years seem to be favouring the concept of a group of initial cells forming the apex.

Observations

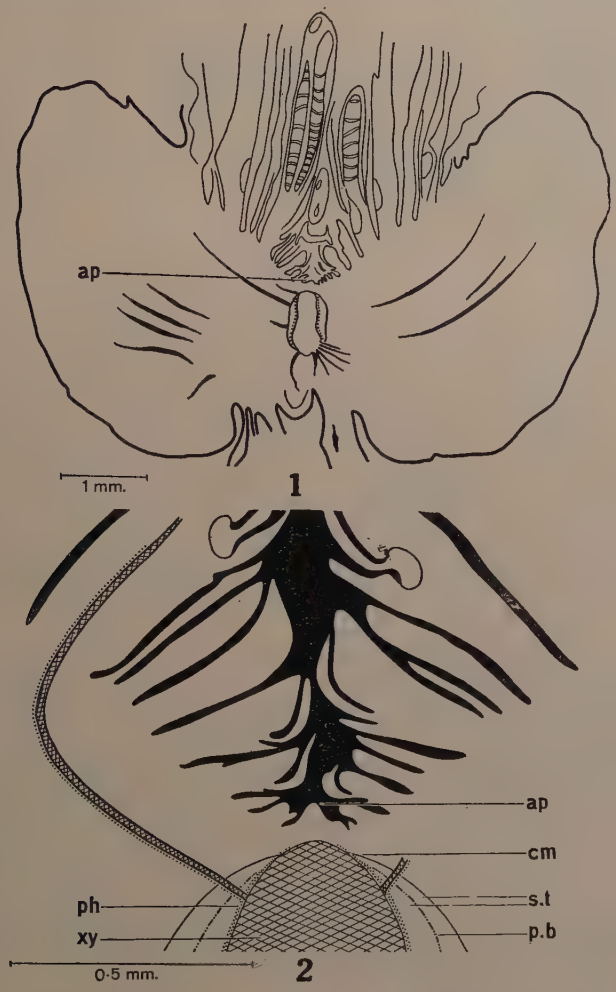
The observations recorded here are based on longitudinal sections although some transverse sections also have been studied for verification. The growing point of the stem is situated at the base of a conical depression (Text-Fig. 2). It is a dome-shaped structure adequately protected by a rosette of leaves, sporophylls and scales present in every stage of development. It cannot, therefore, be observed from outside.

The apical protuberance exhibits variations in form at different stages of ontogeny. It assumes different shapes as the development progresses. In very young apices it is somewhat flattened, the highest point being about 25 μ vertically up from the primordium of the last leaf (Text-Figs. 3 and 4). This condition is seen in corms with about 6–15 leaves. But with further growth, the apex elongates more rapidly and becomes dome-shaped. This condition is obtained in plants with 20 or more leaves. Here the highest point is near about 45 μ away (vertically) from the primordium of the last leaf (Text-Figs. 6 and 7). Finally in fully mature plants it again becomes somewhat flattened (Text-Fig. 8). This form of the apex is apparently correlated with the mode of growth of the axis. In very young plants, as also in mature ones, radial growth is more pronounced than vertical growth, while in the prime youth of its life the plant elongates most rapidly and possesses, though for a short time, a conical apex.

There is an outer epidermal layer that consists of somewhat prominent cells that are thin-walled, those on the lateral flanks, however, may be slightly thick-walled. But all of them lack cuticle as indicated by a negative reaction to Sudan IV. Leaf epidermal cells, on the other hand, give a positive reaction with this chemical. In the past, leaf primordia have been confused with shoot apices (*cf.* Scott and Hill, 1900), but now they can be easily distinguished with the help of this reaction.

The superficial layer of shoot apex is composed of somewhat columnar cells that are equal in size (Text-Figs. 3–8). The cytoplasm of these cells is less vacuolated than that of the internal ones. They divide most frequently anticlinally (Text-Figs. 5 and 8) and thereby

seem to bring about an increase in surface growth in a very general sense. Usual periclinal divisions, however, occur on sides at places where a leaf buttress is to arise (Text-Fig. 8). Rarely some periclinal divisions



TEXT-FIGS. 1–2. Fig. 1. *I. engelmanni* A. Br. Median longitudinal section through the growing stem apex showing its burried nature. Fig. 2. *I. coromandeliana* L. Median longitudinal section through the growing point.

ap., Apex; *cm*, Cambium; *s.t*, Secondary tissue; *p.b*, Parenchymatous band; *ph*, Primary phloem; *xy*, xylem.

also have been observed somewhat higher up on the sides of the apex obviously above the level of the formation of leaf buttresses but they are indeed very few, in the entire study just four cases of this type having been observed.

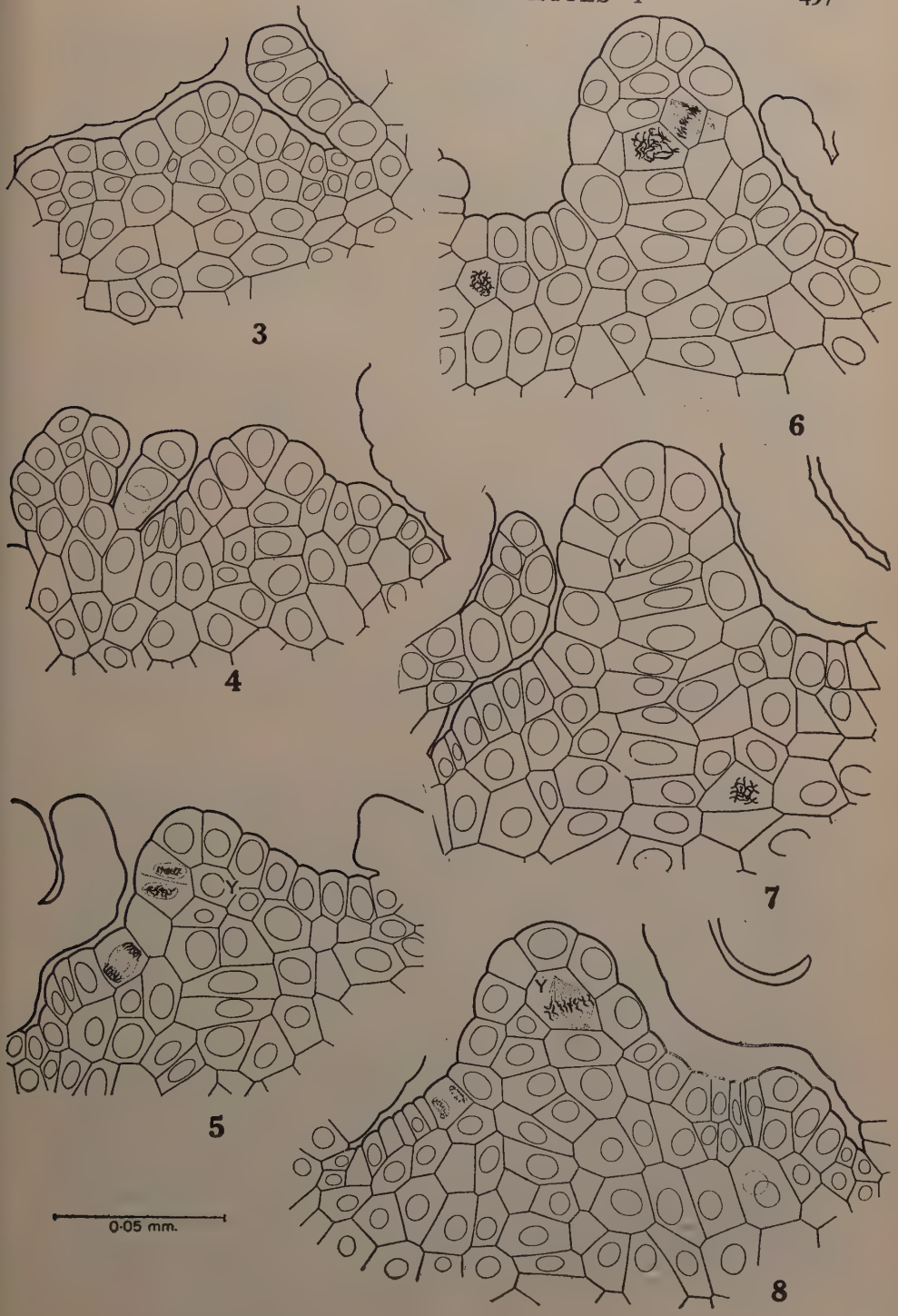
In the underlying tissue beneath the superficial layer, divisions occur irregularly in all directions (Text-Figs. 6–8) but they have almost the same frequency throughout. This results in a peculiar corm-like stem that is very short and stunted. However, beneath a newly-formed foliar buttress the divisions are always more frequent (Text-Fig. 13). This is apparently associated with the formation of the protuberance of a leaf primordium. The cells in this region are irregularly arranged and somewhat larger than the cells of the superficial layer. They are highly vacuolated and noticeably thin-walled. The stratification, arrangement and appearance of these cells do not indicate any direct relationship with the cells of the superficial layer (Text-Figs. 5–8). For instance, it cannot be suggested that they have been derived directly from the superficial cells.

In a transverse series the stem apex appears to be a circular structure (Text-Figs. 9–12) surrounded on all sides by young leaves and ligules in different stages of development. Gradually these leaves get raised up as the peripheral portion of the axis grows faster than the cells at the apex. Transverse sections of the central apex also reveal clearly the difference in structure and shape between the cells of the superficial layer and those inside (Text-Fig. 9). At a higher level, as the section passes through the conical apex there are generally three cells (Text-Fig. 12) all similar in size and shape. In none of the cases examined, there was any indication of there being a single triangualr apical cell at the apex. Occasionally, in oblique transverse series, one of the three cells may appear to be somewhat larger. May be that earlier reports of a single apical cell are based on such series.

During the present study an attempt was made to determine the metabolic activity of the different regions of a growing apex by counting the number of cell divisions taking place in them. In all over 250 median sections of apices showing some division figures were examined. A counting of the division figures revealed that they are three times as numerous below leaf buttresses as in the extreme apical region (Text-Fig. 13). This means that in *Isœtes* lateral growth is much more dominant over apical growth.

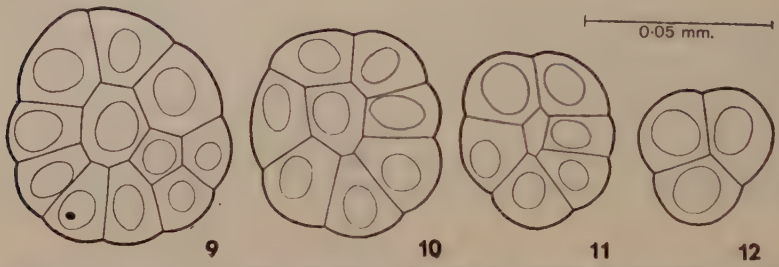
Abundant starch grains are present in the cells occurring 30–40 μ below the growing point. They are, however, absent from the extreme apical region and from very young leaf primordia.

Some apices of *I. engelmanni* have also been studied (Text-Fig. 1), both in longitudinal sections parallel to the plane of the grooves and parallel to the ridges and in transverse sections. Here also the stem consists of an apical protuberance of meristematic tissue. Although no division stages have been observed, the same two regions—an outer superficial layer of more or less columnar cells and an underlying tissue with irregularly arranged cells can be made out as in *I. coromandeliana*. In none of the sections a single apical cell was ever determined.

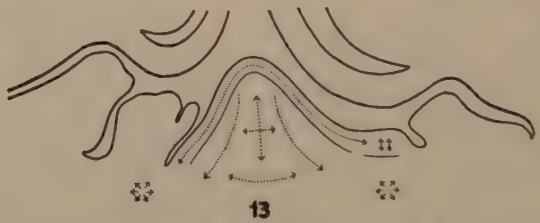


FIGS. 3-8

TEXT-FIGS. 3–8. *I. coromandeliana* L. Median longitudinal sections through the shoot apex of different ages. Figs. 3 and 4. Apices of very young plants—note the flattened nature of the apex. Figs. 5–7. Apices of middle sized plants—note the conical nature of the apex. Fig. 8. Apex of an old plant.



TEXT-FIGS. 9–12. *I. coromandeliana* L. Serial transverse sections through the stem apex showing three cells at the upper conical extremity.



TEXT-FIG. 13. Diagrammatic representation of the planes of division occurring in different regions of *Isætes* stem apex; the small vertical arrows on the right show the initiation of leaf by periclinal walls.

DISCUSSION

As has already been alluded to, there are many controversial issues in the anatomy of *Isætes*. One of them is the organization of the shoot apex. The review of previous literature reveals two schools of thought: (1) that there is a single apical cell and (2) that there is a group of meristematic cells either forming an apical layer or a group of cells at the extreme apex. The fact that each of these views is supported by important personalities itself shows that the problem is not an easy one. Let us, therefore, examine critically these different views.

Apical Cell Hypothesis.—After the formulation of the 'classical concept of a single apical cell" by Hofmeister (1857) and Nägeli (1878), many subsequent researchers attempted to apply it to a much larger number of plants. It was, however, Hofmeister (1869) who first asserted the occurrence of a single apical cell in *Isætes*. This was later supported by van Tieghem (1891) and Scott and Hill (1900) who traced a single triangular apical cell in *I. hystrix*. It appears that de Bary (1884) also favoured the view of a single apical cell in *Isætes* in a restricted sense.

In the present study of *I. coromandeliana* and *I. engelmanni* no definite apical cell like the one occurring in Equisetaceæ, Marattia-

ceæ, *Dryopteris* (Wardlaw, 1953), *Cyathea* (Wardlaw, 1953), etc., could be made out. Nor even a cell arrangement warranting the existence of a single apical cell could ever be observed. If there were a single apical cell, the other cells on either side of it should have been as a rule smaller than the apical cell itself. Besides, the apical cell should not have any basal cells other than those cut off by the lateral cells. For instance the occurrence of the cell marked Y in Text-Figs. 5, 7 and 8 cannot be reconciled with the supposed existence of an apical cell.

Scott and Hill (1900) have given a figure illustrating an apical cell in a transverse section. This figure (Text-Fig. 1) is most unconvincing.

The condition in other members of the Lycopsida, as will be seen subsequently, lends little support to the apical cell hypothesis. In none of them the occurrence of a single apical cell is strictly adhered to except in some species of *Selaginella* where a single apical cell or two cells are reported either in earlier stages or functioning in old stages too (*cf.* Barclay, 1931 ; Williams, 1931 ; Campbell, 1940 and Esau, 1950).

Many-celled Meristem Hypothesis.—Hegelmaier is quoted by Scott and Hill (1900) and West and Takeda (1915) as describing the entire superficial layer of the growing apex as meristematic in nature. He apparently made no attempt to identify a definite group of initials. Farmer (1890) also described that in *I. lacustris* "The entire apex of the stem is covered by a columnar layer of cells, which divide chiefly anticlinally, periclinal divisions only occurring at rare interval." Farmer's description is obviously incomplete in so far as he did not say anything as to the nature of cells occurring beneath this superficial layer.

On the basis of the observation recorded here the present author is inclined to believe that the entire conical apex is somewhat meristematic. It never shows much of activity as the stem is always very short and discoid. In a very general sense it can be distinguished into two regions, an outer superficial layer and an inner zone of meristematic cells. The superficial layer is distinct in so far as it consists of uniformly large cells that divide mostly anticlinally. That it cannot be described as dermatogen or as tunica is clear from the fact that occasionally its cells undergoes periclinal division as well. For that reason it is not fundamentally distinct from the tissue occurring beneath.

Notwithstanding a very thorough search, no zonation could be determined in the tissue internal to the superficial layer. Here the cells divide sparingly and irregularly. Most of the cells in this region are no less meristematic than those in the superficial layer. It is, therefore, futile to attempt to discover here a still smaller group of initials confined to the uppermost part of the stem apex only as proposed by Bruchmann (1874). Smith (1900), West and Takeda (1915), etc. on the other hand, observed a group of meristematic cells but they did not go into details of the subject. Lang (1915 *a* 1915 *b*) has also

arrived at a similar conclusion in a restricted sense as he did not altogether exclude the existence of a single cell in some cases.

It will be worth while at this stage to see the condition in other members of the Lycopsida. Working on *Lycopodium complanatum* Wigglesworth (1907) came to the conclusion that no definite apical cell could be made out in the species, " the actual apex appeared to be occupied by several large cells equal in size....."

Turner (1924) while studying *L. lucidulum* with Professor W. J. G. Land asserted that he has " never been able to trace the origin of the stem tissues to a single apical group, much less to a single apical cell ". He traced dermatogen and periblem to a superficial group of cells and plerome to an internal group of cells. Later on Spessard (1928), another student of Prof. Land, working on the same species of *Lycopodium* observed an apical meristem extending downward up to 70 μ. He segregated two distinct regions—an apical one up to 15 μ level and a sub-apical one downwards up to 70 μ level. The apical region, according to him, consists of an actively dividing epidermis and an inner fundamental tissue.

More recently Barclay (1931) also working under Professor Land, discussed at some length the situation in the Selaginellaceæ. According to him there is in *Selaginella* every intergradation, from a single apical cell to a general meristematic group. He refers to the works of Pfeiffer, Treub, Hofmeister and his own, reporting 2-, 3-, or 4-sided apical cells in one and the same or different species of *Selaginella*. He also draws attention to Bruchmann (1897) who in *Selaginella spinulosa* found apical growth taking place by means of a general meristem, as in the Lycopodiaceæ, and to Strasburger (1891) who reported a group of two initial cells in *S. wallichii*. Williams (1931) also confirmed the observations of Strasburger on *Selaginella grandis*. He also found two initials roughly rectangular in form in vertical sections and in surface view of the apex. Successive vertical anticlinal divisions in these give rise to a row of segments similar to the parent initials on its either side. Further divisions on dorsal and ventral sides add small rectangular cells.

In *Phylloglossum* the problem has not been studied so far but Wernaham (1910) makes a suggestion that here too the growth is not by a single apical cell.

Thus there appears to be no uniformity in different members of the Lycopsida in so far as the organization of their shoot apices is concerned. They are all highly specialized in their own way.

Summary

This paper describes the organization of shoot apex in the locally occurring species—*I. coromandeliana* and also that of *I. engelmanni*—a native of U.S.A. Though nothing strikingly different from what has already been described by Smith (1900) and West and Takeda

(1915) has been found, it has nevertheless become clear from the structure, arrangement and division behaviour of cells that there is a hump of meristematic cells distinguishable into two more or less well demarcated regions—an outer layer of cells covering an inner dome. Divisions are common in these regions—the superficial one having chiefly anticlinal divisions while the inner tissue has irregular divisions. In form, the apex varies from a very low mound to a dome-shaped structure and then again becomes slightly flattened.

A critique of the previous literature has also been made and it has been found that except *Selaginella* in which a gradation from a single to a group of cells has been observed other members of Lycopsida also possesses a group of initials. No evidence has been found of a permanent 'apical cell' or 'an apical cell surface' or a 'smaller mass of central cells' as has been proposed by previous workers in different species of *Isætes* from time to time.

Acknowledgments

I take this opportunity to express my sincere gratitude to my respected teacher Prof. V. Puri, whose keen interest in the problem has made this work possible; to Dr. Y. S. Murty and Mr. S. K. Roy who have helped me in various ways; and also to all my colleagues who have evinced keen interest in my work and especially to Mr. H. P. Sharma and Mr. V. P. Dube for their generous help.

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FLORAL MORPHOLOGY OF THE FAMILY COMPOSITÆ

I. The Flower and the Gametophytes of *Flaveria repanda* Lag.

By S. Misra

Department of Botany, Government College, Ajmer

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Introduction

Morphologically the family Compositæ has received considerable attention. Nevertheless, in view of lack of information regarding some tribes and a number of genera, our knowledge is far from satisfactory. The Helenieæ has been recognised as one of the artificial tribes that needs further study and reclassification (Benthem, 1874; Small, 1919). *Flaveria repanda*, a member of the sub-tribe Flaveriinæ, which remains hitherto undescribed by the morphologists, has been investigated here.

Material and Methods

Flower heads of various ages, after being cut into small pieces, were fixed in different fixing fluids; acetic alcohol and Nawaschin's fluid, after a prefixation of ten minutes in Carnoy's fluid, gave good results. Dehydration, clearing and embedding were done according to the tertiary butyl alcohol-paraffin method (Johansen, 1940). Sections were cut 8–12 microns thick and stained in safranin-fast green and Heidenhain's iron-alum hæmatoxylin counterstained in orange-G. Some cross-sections for the study of flower were stained in gentian violet-erythrosin.

Flower

A flower with its two connivent bracts represents a simple head. Pappus and the achenial hairs are absent; instead, uniseriate and occasionally biseriate hairs are found on the corolla externally, denser at the base with reticulate thickenings in basal and upper cells. Similar thickenings also occur in cells lying below the epidermis in this region. The corolla, in a hermaphrodite floret, is campanulate, composed of five petals (Text-Fig. 6) while in a female ray floret it consists of a highly reduced anterior lip, the posterior lip being suppressed (Text-Fig. 13). The vascular supply of the corolla is characteristic of the Compositæ (Koth, 1930). The five epipetalous stamens with syngenesious anthers resemble with type 3 of stamen forms in Compositæ (Small, 1919). The style in a tubular floret corresponds to Type IV and in a ray floret to Type XII of the style forms, whereas Small (1919) records only Type IV for the Flaveriinæ. The inferior ovary is

bicarpellary, syncarpous, unichambered with a basal anatropous ovule (Text-Fig. 1). The bracts and corolla are persistent.

Abnormal Flowers

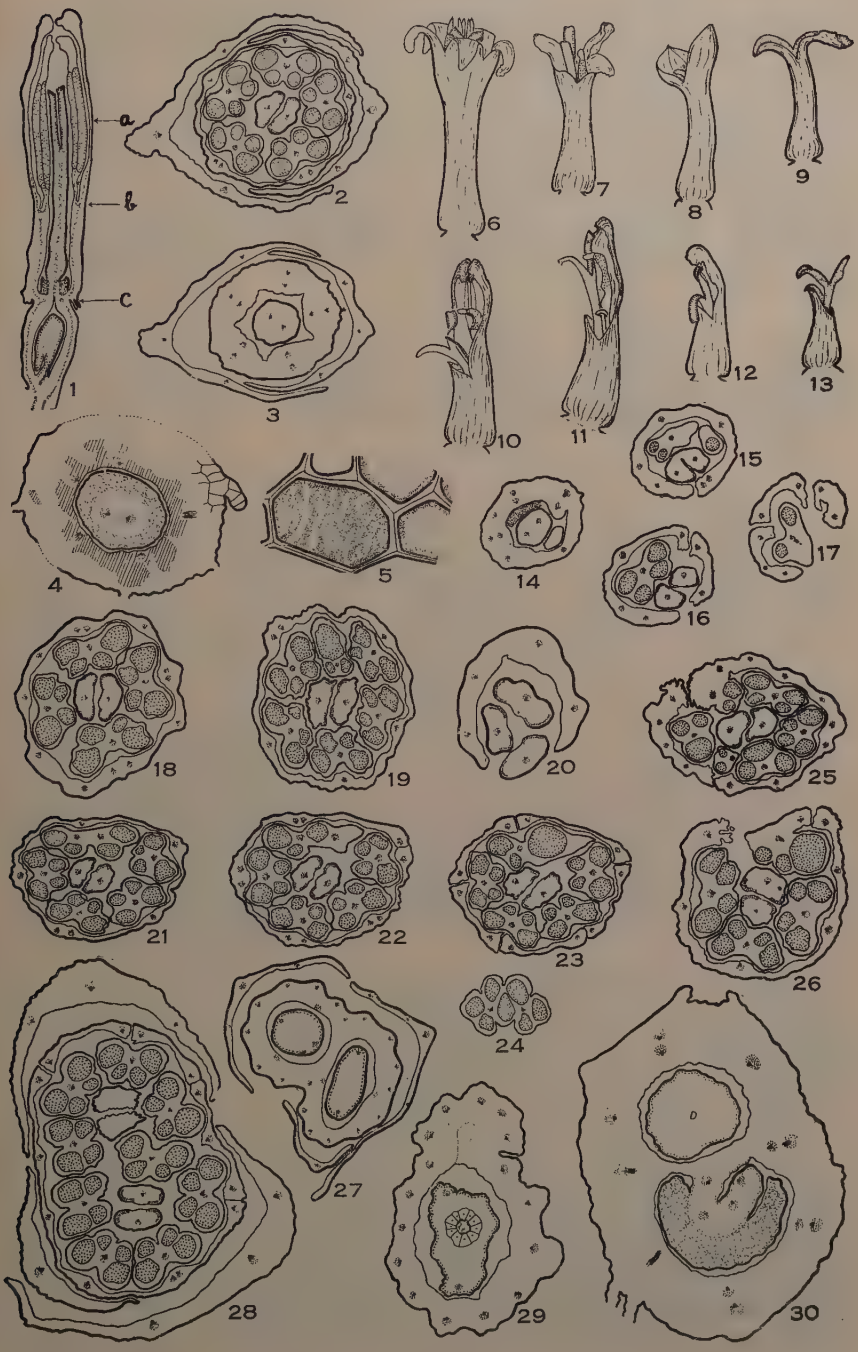
A tendency towards bilabiate construction of corolla is indicated in some tubular florets by a separation of three of the corolla lobes from the remaining two to form anterior and posterior lips respectively. Further, reduction in corolla is initiated by a gradual fusion of the two lobes ultimately resulting into a broad lip. Florets having four corolla lobes and four stamens represent a concurrent reduction which, however, is not always the case. Some florets with five petals have only four stamens (Text-Fig. 18). A floret having three corolla lobes showed one well-developed stamen, a partially fertile stamen and a staminode (Text-Figs. 14–17). Another tubular floret with a three-lobed corolla showed only one stamen. Its stylar arms without the apical hairs, were more or less of the ray floret type.

In some ray florets the posterior lip of the corolla also develops (Text-Fig. 12) and rarely both the lips become equal (Text-Figs. 8, 9). In two such bilabiate florets some rudimentary stamens were also seen (Text-Figs. 10, 11) and in one of them the stylar arms simulate that of the tubular floret but for the presence of scanty apical hairs, it may represent an intermediate condition between the two types.

A couple of ray florets with a bicarpellary gynæcium showed three stylar arms (Text-Fig. 20). The vascular supply in one of them makes it evident that the anterior arm is normal while the other two are the result of bifurcation of the posterior arm. In *Helianthus annus* (Joshi, 1934) and *Wedelia calandulacea* (Sundararaj and Balsubramanyam, 1957) three stylar arms have been seen in tricarpellary gynæcia. Some florets having six petals and six stamens possess bicarpellary gynæcia instead of tricarpellary ones as known in *Helianthus annus* (Joshi, 1934).

Quite frequently median supply appears in some of the corolla lobes (Text-Fig. 18). In some florets with five petals and six stamens, the extra stamen is generally supplied by a median petal bundle (Text-Fig. 19). The extra stamen accommodates in the staminal whorl and creates some deformities; it affects the size of other stamens and itself may acquire an abnormal form (Text-Fig. 19). Sometimes it coheres with an adjacent stamen throughout its whole length (Text-Figs. 21–24) or only partially. Adnation of a stamen with a petal margin has been noted in a few cases (Text-Figs. 25, 26).

Fusion in pairs of florets also occurs. The ovaries of two ray florets fused to form a bilocular ovary with one ovule in each locule as reported in *Helianthus annus* (Joshi, 1934) and *Lonicera* (Arber, 1903; Wilkinson, 1945). Complete fusion of tubular florets accompanied by a significant reduction also takes place. In one case there has been a uniseriate nine-lobed corolla, nine stamens and two normal styles (Text-Fig. 28) on a fused bilocular ovary with one ovule in each locule (Text-Fig. 27). The other has only eight corolla lobes, eight abortive stamens



TEXT-FIGS. 1–30

TEXT-FIGS. 1–30. Fig 1. L.S. Tubular flower-bud, showing annular nectary, bifid style and epipetalous stamens, ×27. Fig. 2. T.S. at *a* in Fig. 1, ×62. Fig. 3. T.S. at *b* in Fig. 1, showing the split of staminal bundles, ×62. Fig. 4. T.S. at *c* in Fig. 1, showing the region of thickened cells by lines, ×62. Fig. 5. Some thickened cells magnified, ×850. Figs. 6, 13. Epigynous portions of tubular and ray florets, the hairs outside corolla not shown, ×15. Figs. 7–12. Epigynous portions of various bilabiate florets, ×15. Figs. 14–17. T.S. at various levels of epigynous portion of an abnormal bilabiate floret, ×62. Figs. 18–30. T.S. of abnormal florets, ×62. Figs. 18, 19. T.S. anther region. Fig. 20. T.S. stylar region. Figs. 21–24. T.S. epigynous portion at various levels from below upwards. Figs. 25, 26. T.S. anther region. Figs. 27–30. T.S. florets showing adnation. Figs. 27, 29. T.S. through ovaries. Fig. 28. T.S. anther region. Fig. 30. T.S. nectary region.

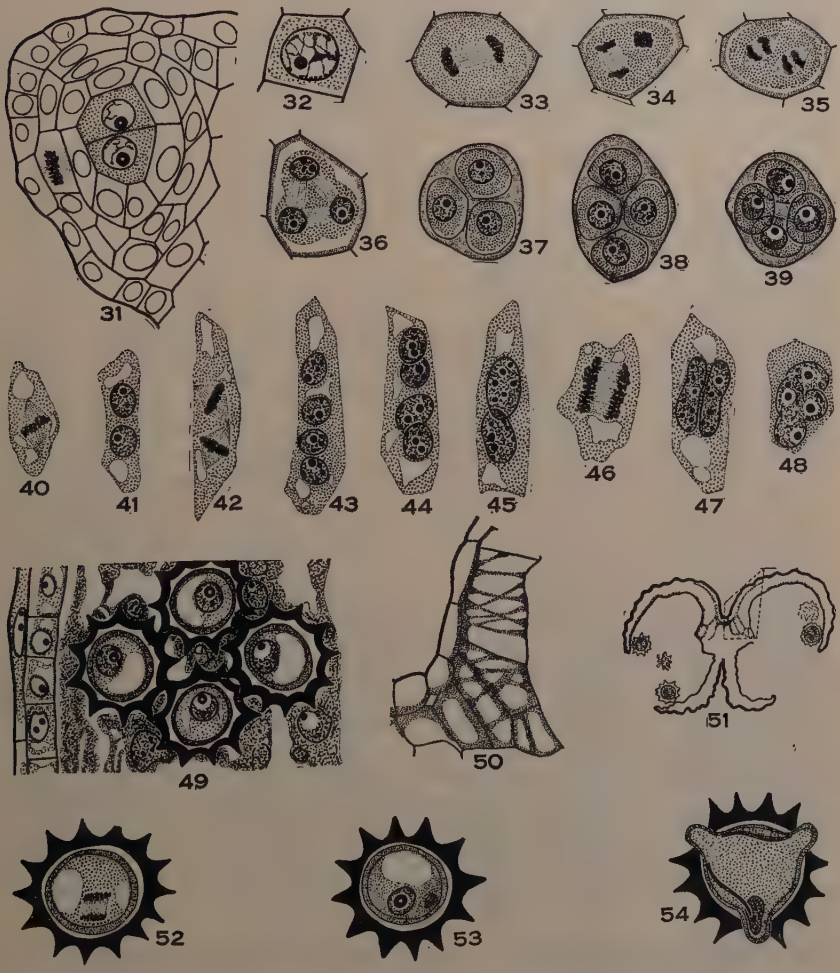
and two abortive styles (Text-Fig. 30). The fused ovary has one of the locules suppressed and the other comparatively large with an ovule in it (Text-Fig. 29). Joshi (1934) also describes some cases of fusion of florets in *Helianthus annus* accompanied by a reduction in them.

MICROSPOROGENESIS AND THE MALE GAMETOPHYTE

Floral organs develop in an acropetal succession. In the anther, the archesporium consists of a longitudinal hypodermal layer in each lobe which undergoes a periclinal division forming a primary parietal and a primary sporogenous layer. The former cuts tapetum towards inside while its outer derivative divides once again periclinally giving rise to a middle layer and the endothecium (Text-Fig. 31). The peripheral locules are larger and remain at a slightly advanced stage than the inner ones as seen in *Silphium* (Merrel, 1900) and *Eclipta erecta* (Bhargava, 1935). All the stages of meiosis can be seen in the anthers of a single floret but within a locule there is perfect synchronisation. The sporogenous cells may divide but once giving rise to the microspore mother cells which round up and develop a mucilage pallicle between their protoplasts and the cell-walls. Simultaneous meiotic divisions in the spore mother cells and quadripartition by furrowing results, more commonly, in tetrahedral tetrads (Text-Fig. 37) and quite frequently in decussate tetrads (Text-Figs. 38, 39).

When the microspore mother cells are in synezesis the tapetal cells are already binucleate (Text-Figs. 40, 41). A second nuclear division follows (Text-Fig. 42) and results into tetranucleate tapteal cells (Text-Fig. 43). Fusion of the two spindles during division produces two cylindrical nuclei (Text-Figs. 46, 47). In *Blumea laciniata* (Banerji, 1942) and *Mikania scandens* (Mitra, 1947), similar nuclei are formed due to fusion in four spindles. Of the four nucleate cells the nuclei may fuse in pairs (Text-Figs. 44, 45) or all in one irregular mass (Text-Fig. 48). The tapetal nuclei, therefore, show fusions and divisions resulting into polyploid nuclei of diverse forms. When the microspore tetrads are being formed, the tapetal cells begin to lose their cell-walls, their protoplasts project into the locule, fuse therein and result into periplasmodium enclosing the uninucleate microspores (Text-Fig. 49). The periplasmodium is consumed during the maturation of the pollen grains.

Uninucleate microspores develop a membrane around them. The formation of exine and intine follows. Microspores enlarge and develop a central vacuole (Text-Fig. 49) which pushes the nucleus towards the periphery where it divides (Text-Fig. 52) and gives rise to a bicelled pollen grain (Text-Fig. 53). By this time the middle layer completely degenerates. When the pollen grains are mature the endothecium



TEXT-FIGS. 31–54. Microsporogenesis and Microgametogenesis. Fig. 31. T.S. anther lobe, showing sporogenous cells and wall layers. Fig. 32. Microspore mother cell. Figs. 33–35. Meiosis I and II. Fig. 36. Cytokinesis. Fig. 37. Tetrahedral tetrad. Figs. 38, 39. Decussate tetrads. Figs. 40–48. Tapetal cells. Fig. 49. L.S., portion of anther locule, showing uninucleate microspores and periplasmodium. Fig. 51. T.S. anther showing thickenings on the outer face. Fig. 50. Same, a portion magnified. Fig. 52. Microspore nucleus in division. Fig. 53. Bicelled pollen grain. Fig. 54. Tricelled pollen grain. (Fig. 51, ×167; others, ×850.)

has large cells with radial bands of fibrous thickenings (Text-Figs. 50, 51). Thickenings also occur on their inner tangential walls (Text-Fig. 50). The epidermal cells in the connective region also enlarge and develop thickenings on their inner tangential walls which extend to some of the underlying layers (Text-Figs. 50, 51). At shedding stage the pollen grain is spheroidal, tricolpate and tricelled with an intine and spinulose exine (Text-Fig. 54). Pollen grains sometimes show incipient germination *in situ*, the tube nucleus enters one of the papilla through the germ pore and the gametes follow it (Text-Fig. 54). In *Silphium*, Merrel (1900) found some pollen grains germinating *in situ*.

There is considerable degeneration of microspores at all stages of development resulting in a small fraction of fertile pollen grains. In *Eclipta erecta*, Bhargava (1935) noted degeneration in microspore tetrads.

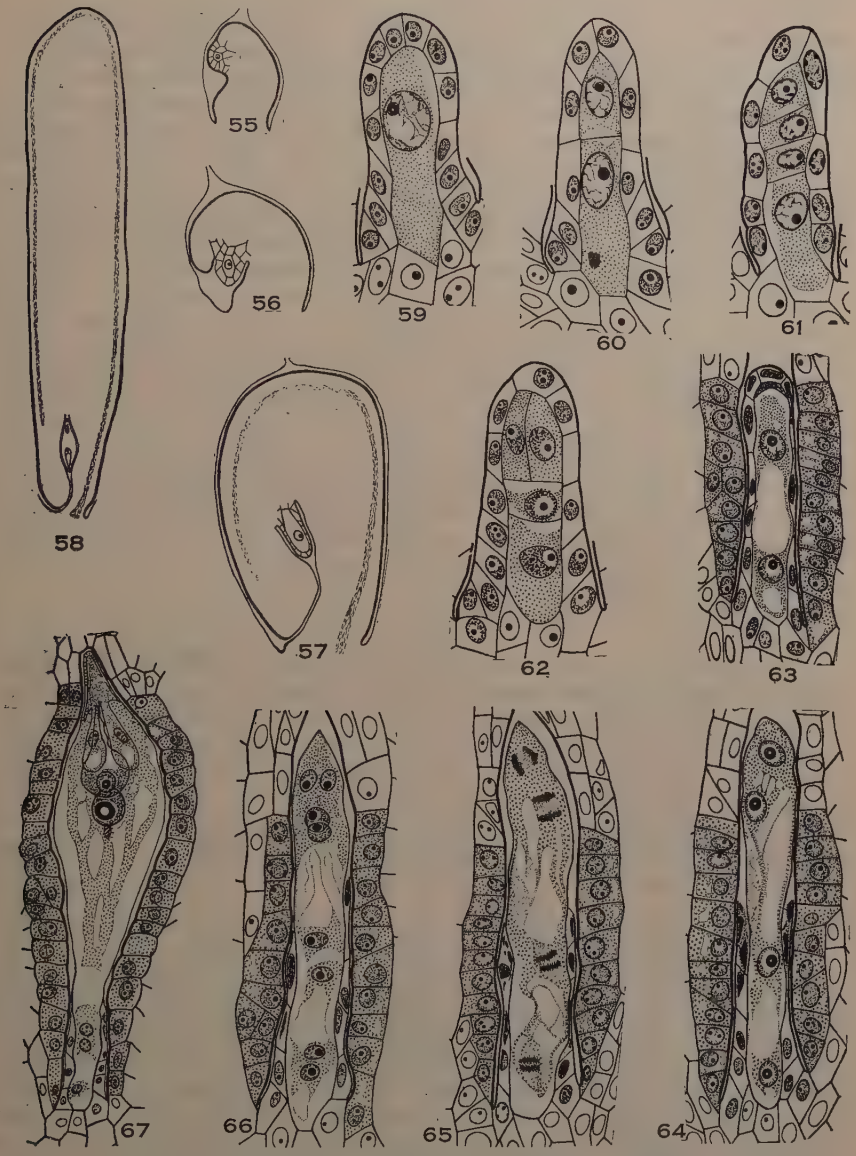
Ovule

The ovule is unitegmic and tenuinucellate. It arises as a triangular protuberance at the base of the ovarian chamber. Hypodermal archesporial cell and the integumentary primordia appear simultaneously (Text-Fig. 55). Owing to its unilateral growth the ovule inverts and becomes anatropous by the time the megaspore mother cell matures (Text-Figs. 56, 57). After this it undergoes considerable elongation (Text-Fig. 58). A single vascular supply enters the funiculus and reaches very near the tip of the integument on the other side as seen in *Tridax procumbens*, *Tagetes patula* and *Zinnia elegans* (Venkateswarlu, 1941).

Degeneration in the nucellar epidermis starts from the middle towards the micropyle. The nucellus in the region of the antipodals persists for long (Text-Fig. 67). The innermost layer of the integument along the sides of the embryo-sac differentiates early as uniseriate endothelium. At the maturity of the megagametophyte some oblique divisions, as reported in *Mikania scandens* and *Ageratum conyzoides* (Mitra, 1947), take place at the two ends of the endothelium and followed by a few more divisions, in case of abnormally enlarged embryo-sacs, result into broad patches. Double layers in patches have been reported in *Helianthus annus* (Carano, 1915). The middle layers of the integument adjacent to the integumentary tapetum begin to degenerate at this stage.

Megasporogenesis and the Development of Embryo-sac

The archesporium directly functions as the megaspore mother cell (Text-Figs. 57, 59). First meiotic division of the spore mother cell results into a dyad of two unequal cells (Text-Fig. 60) and the second into a tetrad of megaspores generally arranged in a linear row (Text-Fig. 61), rarely in shape of 'T' (Text-Fig. 62). The chalazal megaspore invariably functions as the embryo-sac mother cell while the remaining three degenerate starting from the chalazal towards the micropyle as in *Galinsoga ciliata* (Popham, 1938). The degenerated



TEXT-FIGS. 55–67. Megasporogenesis and Megagametogenesis. Figs. 55–58. Development of ovule. Fig. 59. Megaspore mother cell. Fig. 60. Dyad. Fig. 61. Linear tetrad. Fig. 62. T-shaped tetrad. Fig. 63. 2-Nucleate embryo-sac with degenerated megaspores. Fig. 64. Four-nucleate embryo-sac. Fig. 65. Same, in division. Fig. 66. 8-Nucleate embryo-sac. Fig. 67. Same at maturity. (Figs. 55–57, ×167; Fig. 58, ×39; Figs. 59–62, ×755; Figs. 63–66, ×625; Fig. 67, ×371.)

megaspores are seen forming a cap over the two-nucleate embryo-sac (Text-Fig. 63). The latter undergoes simultaneous nuclear division to result into a four-nucleate embryo-sac which followed by subsequent enlargement breaks through the degenerated nucellar epidermis so that its micropylar end comes to lie in the cavity enclosed by the integument. A vacuole also appears in between the nuclei at the chalazal end (Text-Fig. 64). The next division is not simultaneous in all the four nuclei (Text-Fig. 65). The organised embryo-sac clearly shows sister nuclei relationship as observed by Popham (1938) in *Galinsoga ciliata* and by Martin and Smith (1955) in *Chrysanthemum leucanthemum* and results into an eight-nucleate, six-celled female gametophyte. Large number of embryo-sacs at this stage show complete degeneration while in some only the egg apparatus degenerates similar to *Eclipta erecta* (Bhargava, 1935). In the mature embryo-sac the synergids are hooked and they project into the micropyle. Egg is pear-shaped with a long basal vacuole. Polars fuse early and the secondary nucleus comes to lie in the vicinity of the egg. There are only two antipodals, one uni- and the other bi-nucleate in the narrow chalazal end of the embryo-sac. They persist without further division in them, for long. Mitra (1947) noted a similar case in *Ageratum conyzoides* and called attention to a number of such cases in the Compositæ.

Discussion

A tendency towards economy which has been dominant throughout the development of the family is well expressed in the present species. The aggregation of a number of inflorescences to form glomerule, the modifications in some already existing floral organs for the compensation of pappus, the reduction of corolla in ray florets which get little room for their exposition and a modification in their style due to complete obliteration of the apical brush of hairs whose function of sweeping the pollen through the anther tube is no more required are some significant features in this direction.

The tubular florets showing a bilabiate construction may be taken as examples of retrogressive mutation (Coulter, 1915) while the presence of stamen rudiments in some female rays is a reversionary feature. All these chance variations met with herein, arranged in an ascending series, may suggest some stages through which the hermaphrodite tubular floret might have undergone during the course of evolution, to give rise to a female ray floret. In view of the sporadic occurrence of posterior lip in the ray florets of some members of the Heleniæ, which is a feature of the present species also, Small (1919) has related this tribe with the sub-tribe Galinsogineæ (tribe Helianthæ).

The absence of pappus is accompanied by the absence of achenial hairs (*cf.* Small, 1919). The persistence of corolla by the development of thickenings in its basal portion and of bracts enclosing a fruit probably help in the dispersal of fruits by wind and thereby compensate for the pappus.

The appearance of a median bundle in some of the corolla lobes is a primitive feature (Koch, 1930).

The relationship of the two stylar types, IV and XII (Small, 1919) is quite significant from the occurrence of transitional forms met with in the present material.

Modifications in the florets or in some of their parts under cohesion and adnation, hitherto described, may be assigned to the spatial difficulties for their fuller exposition, created by the fasciculation of the inflorescences.

Summary

The flower and the gametophytes in *Flaveria repanda* have been described.

A flower with its two connivent bracts represents a simple head. Pappus and the achenial hairs are absent. The corolla with its hairs and the bracts persist, probably for the compensation of pappus. The stamen conforms to Type 3 while the style to Types IV and XII Small, (1919).

The various bilabiate florets met with may throw some light on the development of the female ray from the tubular hermaphrodite floret, during the course of evolution.

Other floral abnormalities observed herein might be due to existing spatial difficulties.

The floral parts develop in an acropetal succession. In the anthers the archesporium is hypodermal.

The spore mother cells after simultaneous I and II meiotic divisions give rise to tetrahedral as well as decussate tetrads. Cytokinesis takes place by furrowing.

The anther tapetum shows a tendency towards the formation of polyploid nuclei, ultimately giving rise to a periplasmodium.

The shedding pollen grains have a spinulose exine and are spheroidal, tricolpate and tricelled with long and curved gametes; at times show an incipient germination *in situ*.

The ovule is anatropous, unitegmic and tenuinucellate. The integumentary tapetum differentiates early. Broad patches at the two ends are formed in abnormal cases.

The hypodermal archesporial cell functions directly as the megaspore mother cell. The megaspores arrange in tetrahedral and rarely in 'T'-shaped tetrads. The chalazal megaspore invariably functions as the embryo-sac mother cell. The embryo-sac is of monosporic Polygonum-type but organises into only six cells. The antipodals persist without further division in them.

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MALE AND FEMALE GAMETOPHYTES OF *IONIDIUM SUFFRUTICOSUM* GING.

By P. K. Mukherjee and P. Venugopalan

Department of Botany, College of Science, Nagpur

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Introduction

Violaceæ is a family of herbaceous plants with 18 genera and about 800 species. It has a wide range of geographic distribution and is represented in India by 3 genera and 24 species (Hooker, 1872).

So far, only two genera, *Viola* and *Hybanthus*, have been studied embryologically. The literature has been reviewed by Schnarf (1931). Souèges (1937) described in detail the embryo development in *Viola tricolor*.

The present paper deals with an account of the development and structure of the male and female gametophytes of *Ionidium suffruticosum* Ging. a common herb found round about Nagpur and Jabalpur.

Material and Methods

The material was fixed in Formalin-acetic-alcohol and in Navaschin's fluid. Customary methods were followed for dehydration and embedding. Sections were cut 10–12 μ in thickness. They were stained with Heidenhain's iron-alum-hæmatoxylin and destained in a saturated solution of picric acid. Fast green was used as a counter-stain. The pollen grains were mounted in Methyl-green-glycerine-jelly (Wodehouse, 1935).

Microsporangium and Microsporogenesis

The earliest stage observed by the authors in a young anther shows a parietal layer below the epidermis and sporogenous cells on the inner side (Fig. 1). The parietal layer divides periclinally and followed by further divisions it forms four layers. The anther wall including the epidermis thus consists of five layers (Figs. 2–4).

Of the four parietal layers only the two end layers function while the two middle layers degenerate early. At the time the young pollen grains are formed, these degenerating layers are seen as black staining streaks in between the tapetum and the fibrous endothecium (Fig. 4) but they disappear completely at maturity. The layer next to the epidermis forms the fibrous endothecium. A few fibrous thickenings are laid down on the radial walls. The inner tangential walls of the endothecial cells also show the presence of thickening while such thickening is absent on the outer tangential walls of the cells (Fig. 5). Small

yellow staining globular markings appear on the inner tangential wase of these cells during later stages of development as noted by Kajall (1940) in species of Amaranthaceæ.

The innermost layer develops into the tapetum (Fig. 4). The uninucleate tapetum becomes binucleate at a later stage (Fig. 4) and is of the glandular type as in other species of *Viola* (Schnarf, 1931). It degenerates only after the pollen grains are well developed. Prior to its disappearance it shows the presence of numerous small globular markings on its inner tangential side (Fig. 6).

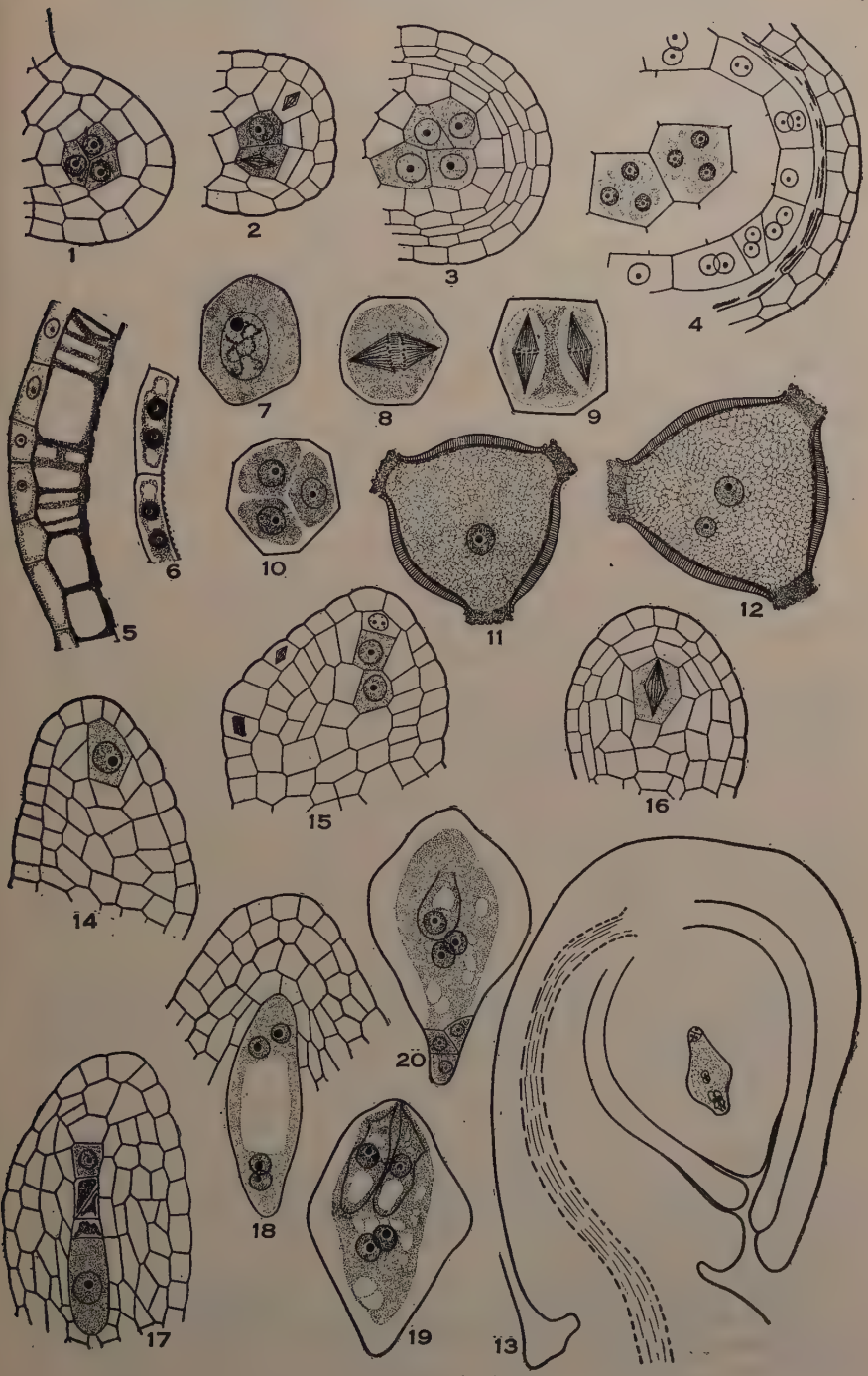
The primary sporogenous cells divide mitotically and increase in number (Fig. 2). The microspore mother cells undergo the usual meiotic divisions (Figs. 7–9). A distinct mucilagenous sheath appears in between the cytoplasm and the cell-wall (Figs. 8 and 9) and it persists till the pollen grains are formed. At a later stage it disappears. At diakinesis stage the cytoplasm in the pollen mother cells is finely vacuolated and the vacuoles show radiating arrangement. Cytokinesis takes place by centrifugal furrowing and the microspores are arranged either in a tetrahedral or isobilateral pattern (Fig. 10).

Microspore

After the pollen grains are liberated in the anther loculus they develop intine and exine. In the beginning the proximal end of the pollen grain is tapering (Fig. 10). But soon it is lost and the pollen grain becomes spheroidal. It is densely filled with cytoplasm throughout its development and is finely vacuolate. The nucleus of the pollen grain divides once and the pollen grain is shed at this stage (Figs. 11 and 12). According to Lagerberg (1909), Bliss (1912) and Gorczynski (1929) the mature pollen grains of *Viola* are two-celled. West (1930) showed that the generative cell may divide in the pollen grain or in the pollen tube. The pollen grain is tricolporate spheroidal and psilate as in most other species of this family (Erdtman, 1952). In *Viola tricolor*, however, the pollen grains are tetracolporate while in *V. arvensis* they are tetra- or penta-colporate. The exine is thickest in the region equidistantly situated between the two furrows and is striated when seen in section. The margin of the exine along the furrow is thinnest and is bent forward and outward. The intine is a delicate membrane and protrudes out of the germ pore. The protruded part of the intine has an undulated margin (Figs. 11 and 12).

Megasporangium

The gynœcium is tricarpellary, syncarpous and unilocular. The ovules are borne on three distinct parietal placentas. The two integuments of the ovule develop from below the level of archesporium. Both the integuments develop simultaneously and form the micropyle (Fig. 13). They are three-layered each except at the micropyle where inner integument is thicker. At the micropylar region the cells of the outer integument are enlarged. The ovules are anatropous and crassinucellate



TEXT-FIGS. 1–20

TEXT-FIGS. 1–20. *Ionidium suffruticosum* Ging. Figs. 1–3. T.S. young anther lobes showing stages in development of anther. Note the mitotic division in the primary sporogenous cell in Fig. 2. Fig. 4. The same as above at an advanced stage. Note the binucleate tapetal cells, two degenerating middle layers and microspore tetrads. Fig. 5. Part of anther wall in T.S. showing fibrous endothecium and epidermis. Note the degenerating layer on the inner tangential wall of the former. Fig. 6. Tapetal cells showing globular markings. Figs. 7–9. Stages in the meiotic divisions of pollen mother cells. Note the presence of perinuclear zone around the spindles in Fig. 9. Fig. 10. Tetrahedral arrangement of young pollen grains. Figs. 11–12. Uni-nucleate and two-nucleate pollen grains. Fig. 13. L.S. ovule at mature embryo-sac stage. Note the vascular supply. Fig. 14. L.S. apex of nucellus showing archesporial cell. Fig. 15. The same showing two megaspore mother cells. Fig. 16. Meiotic division in the megaspore mother cell. Fig. 17. Linear megaspore tetrad with an extra megaspore mother cell at its top. Fig. 18. L.S. apex of nucellus showing epidermal cap and 4-nucleate embryo-sac. Fig. 19. Mature embryo-sac showing synergids and polars. Note its fusiform shape in this and also in the next figure. Fig. 20. The same showing egg, two polars and three antipodal cells. (Figs. 1–6, ×600: Figs. 7–12, ×833 ; Fig. 13, ×233; Figs. 14–20, ×600.)

(Fig. 13) as in other species of the family (Schnarf, 1931). The nucellar epidermis divides periclinally and forms an epidermal cap (Fig. 18).

MEGASPOROGENESIS

The hypodermal archesporium generally consists of one and sometimes of two cells (Fig. 14). Single-celled archesporium is reported in *Viola riviniana* (West, 1930) and in *V. odorata* (Bliss, 1912). According to West (1930) the archesporium in *Viola riviniana* "differentiates in the third layer of cells of the nucellus and becomes the megaspore mother cell direct." But this appears doubtful and needs confirmation. Likewise the statement by Magde (1929) that during later stages "about eight archesporial cells stand out clearly in the middle of the ovule" also needs confirmation. The archesporium cuts off a parietal cell below the epidermis and a megaspore mother cell towards the chalazal side. Sometimes two megaspore mother cells are also observed (Fig. 15). The megaspore mother cell increases in size and divides to form the dyad cells (Fig. 16). Both these cells divide again to form the linear quartet of four megaspores. Sometimes the arrangement is obliquely T-shaped (Fig. 17). Of the four megaspores, three at the micropylar end degenerate while the chalazal one functions (Fig. 17). Bliss (1912), however, has demonstrated that sometimes in *Viola cucullata* the middle megaspore forms the embryo-sac. In one case (Fig. 17) an additional megaspore mother cell was observed immediately adjoining the micropylar end of the quartet.

EMBRYO-SAC

The functioning megaspore increases in size. The nucleus undergoes three divisions and forms the eight-nucleate embryo-sac of the Polygonum type (Maheshwari, 1950).

The mature embryo-sac is fusiform. The synergids are somewhat elongated, hooked and pear-shaped (Fig. 19). In *Ionidium suffruticosum* no filiform apparatus as in *Viola odorata* (Magde, 1929) was observed.

The egg is flask-shaped with nucleus at the base and vacuole at the micropylar end. The two polar nuclei meet below the egg apparatus. The antipodals are three small ephemeral cells (Fig. 20) as in other species of *Viola* (Schnarf, 1931). In *Hybanthus sps.*, however, according to Andrews (1910) they are large.

Summary

The present investigation deals with the development and structure of the male and female gametophytes of *Ionidium suffruticosum* Ging.

The anther wall consists of five layers. The endothecium is fibrillar, the tapetum is glandular and becomes binucleate prior to degeneration. The male archesporium is multicellular. The division of the pollen mother cell is simultaneous. The pollen grains are arranged either in a tetrahedral or isobilateral manner. They are two-celled at the time of shedding and are tricolporate, psilate and spheroidal.

The ovules are anatropous, crassinucellate and bitegmic. The micropyle is formed by both the integuments. Nucellar epidermis forms cap of two or three layers thick below the micropyle.

The female archesporium consists of one or two cells. A parietal cell is cut off. The megaspore mother cell forms a linear quartet of megaspores. Sometimes it is obliquely T-shaped.

Development of the embryo-sac follows the Polygonum type. The synergids are hooked. The egg has usual structure. The antipodal cells are small ephemeral structures occupying the chalazal end of the embryo-sac.

Acknowledgment

We are deeply indebted to Dr. L. B. Kajale for his helpful guidance and criticism throughout the progress of the work.

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OCCURRENCE OF *RAUVOLFIA SERPENTINA* BENTH. IN FORESTS OF WESTERN CIRCLE, UTTAR PRADESH

By V. Chandra

National Botanic Gardens, Lucknow

(Received for publication on June 6, 1957)

Introduction

The following observations are based on tours made by the author in December 1956 in the forests of the Western Circle, Uttar Pradesh (see Map). A few months earlier the author had visited several localities in South Bihar and failed, even after careful search, to observe any specimen of the species in situations where its occurrence was expected. The opinion expressed by Kaul (1956) that *Rauvolfia serpentina* is probably an introduced plant in certain parts of Northern India provided the impetus for a more detailed study of its distribution, and the tours described below were made with this aim.

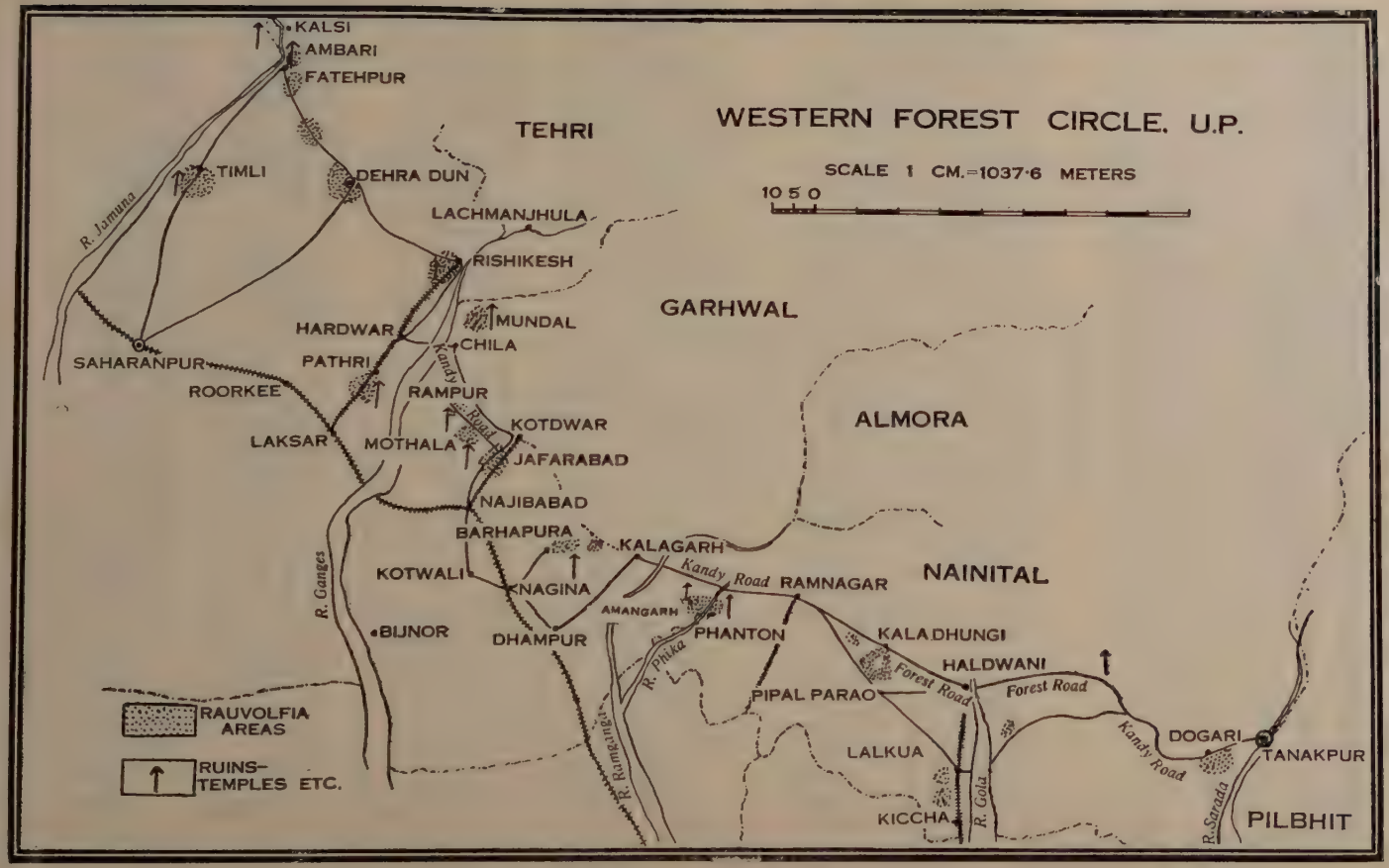
Description

Dehra Dun District.—In this area the author visited the forests of Timli, Kalsi, Ambari and Rishikesh. These forests had a luxuriant vegetation comprising species of *Shorea*, *Mallotus*, *Anogeissus*, *Holarrhena*, *Phyllanthus*, *Bauhinia*, *Terminalia*, *Eugenia*, *Dalbergia*, *Cassia*, *Zizyphus*, etc. *Rauvolfia serpentina* grew in scattered areas under shade of these trees, in association with *Adhatoda vasica*, *Clerodendron infortunatum*, various zingibers and grasses.

At Timli plants in larger numbers were noticed near the abandoned village of this name. Sporadic growth was noticed along several paths as one approached other villages in the vicinity of Timli. The species was also noticed in Ambari forest, mostly by the old road leading to Kalsi. The plants grew in abundance near an ancient 'kund' for 'yagna' said to date from 300 B.C.

Saharanpur District.—*Rauvolfia serpentina* is found in the Pathri forest block, 9 miles south of Hardwar. Here it was seen mostly growing round the edges of pools under the shade of trees and also near ruined wells, bridges and dwellings, in close association with *Adhatoda vasica*, *Piper longum*, *Clerodendron infortunatum*, etc.

Garhwal District.—*Rauvolfia serpentina* occurs in the forests of Ghori range. The areas of growth were found scattered and rather far apart; they are said to be sites of villages now deserted due to ravages of elephants.


WESTERN FOREST CIRCLE. U.P.
SCALE 1 CM.=1037·6 METERS
10 5 0
TEHRI
GARHWAL
ALMORA
NAINITAL
PILBHIT
KALSI
AMBARI
FATEHPUR
TIMLI
DEHRA DUN
LACHMANJHULA
RISHIKESH
MUNDAL
CHILA
HARDWAR
SAHARANPUR
PATHRI
ROORKEE
RAMPUR
Kandy Road
KOTDWAR
LAKSAR
MOTHALA
JAFARABAD
NAJIBABAD
BARHAPURA
KALAGARH
KOTWALI
NAGINA
Kandy Road
RAMNAGAR
AMANGARH
PHANTON
BIJNOR
DHAMPUR
KALADHUNGI
HALDWANI
Forest Road
Forest Road
PIPAL PARAO
LALKUA
KICCHA
DOGARI
Kandy Road
TANAKPUR
R. Jamuna
R. Ganges
R. Ramganga
R. Phika
R. Gola
R. Sarada
RAUVOLFIA AREAS
RUINS–TEMPLES ETC.

Bijnor District.—The forest belt of Bijnor District lies mostly south of the Siwaliks. The belt starts from Chandi Pahari in the north and extends eastwards, along a distance of 80 miles, to the border of Naini Tal District. Through the forest belt passes an old pilgrim route which, running along the Siwaliks, leads to Hardwar and thence to Badrinath. This route known as 'Kandi Sarak' marks the boundary between the districts of Bijnor and Garhwal. The forests contain low lying areas which together with the nalas and rivulets get flooded during rains. The vegetation is of a mixed type, including species of *Shorea*, *Salmalia*, *Butea*, *Acacia*, *Albizzia*, *Terminalia*, *Ficus*, *Phyllanthus*, *Bauhinia*, *Holarrhena*, *Mallotus*, *Adina*, *Anogeissus*, *Zizyphus*, *Lagerstræmia*, *Randia*, *Dendrocalamus*, etc. The undergrowth consists generally of grasses in the open and *Sida*, *Clerodendron*, *Glycosmis* and *Adhatoda* in the shade.

Rauvolfia serpentina was observed growing in five places bearing names within the forest area. At Mothala the plants were seen near a small mausoleum. At Rampur, which is about 10 miles north of Mohala, it was growing under the shade of mango trees by the side of an old well. At Jafarabad the plants were found near old buildings. Copper and silver coins of Allauddin Khilji's time are reported to have been discovered in the fields in the last locality while the forest was being cleared for plantations. The next place where this species was seen was Barhapura, about 30 miles south-east of Jafarabad. Here they occur very close to a number of old brick mounds. An image of Saint Paras Nath was discovered in the vicinity about 2 years ago. The last place to be visited was Amangarh at a distance of about another 40 miles east of Barhapura. *Rauvolfia serpentina* grew here under plantation of *Tectona grandis*. Close to the plantation is a mound regarded as remnant of an old fort.

Naini Tal District.—The boundary between Bijnor and Naini Tal District is formed by the Phika river which flows close to Amangarh. On crossing the river from Amangarh *Rauvolfia serpentina* is seen again, occurring sporadically, up to Phaton. The forest belt of Tarai Bhaber in Naini Tal District extends eastwards from the Phika to the Sharda river. The vegetation is very luxuriant. At places *Lantana camara* forms thick growths. *Rauvolfia serpentina* was here observed in several widely separated areas. The largest number of plants were observed in the Nihal block south of Kaladhungi.

Neer Dogari about 12 miles west of Tanakpur *Rauvolfia serpentina* was observed here and there along a three-mile strip. It was for the first time found growing in association with *Calamus teunis* and ferns. Throughout the forest of the Western Circle large number of abandoned catechu furnaces were also observed.

Summary and Conclusions

Rauvolfia serpentina has been found growing in five districts of the Western Forest Circle of Uttar Pradesh (see Map). The species

grows in shady areas. Its occurrence is sporadic and no continuous belts of it have been found. The plants usually grow scattered, two or more feet apart, very seldom closer. The plants are more frequent under the shade of trees like *Shorea*, *Ficus*, *Terminalia*, *Holarrhena*, *Cassia*, *Delbergia* and *Adina*. At one locality they were found growing between clumps of *Calamus*.

It is noteworthy that wherever the plants of *Rauvolfia* were discovered, they were growing close to the beaten track or to sites of habitation, either ancient or more recently abandoned. As far as the author is able to judge, the association of *Rauvolfia serpentina* with sites of human activity cannot be entirely accidental. Further surveys will probably throw more light on this question.

Acknowledgements

Thanks are due to Prof. K. N. Kaul, Director, National Botanic Gardens, Lucknow, for arranging the tour and extending all facilities to the author. Thanks are also due to the Chief Conservator of Forests, Western Forest Circle, Uttar Pradesh, and to the Divisional Forest and Range Officers who helped the author in visiting the interior of the forests.

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A STUDY OF THE SYMPODIAL HABIT IN AN INTERSPECIFIC CROSS IN *GOSSYPIUM*

By N. R. Bhat[1] and C. T. Patel

Agricultural Research Station, Surat, Bombay State, India

(Received for publication on May 5, 1957)

Early studies of the sympodial habit of growth in the cotton plant have been reviewed by Harland (1938). Ramanathan (unpublished) found that "the environmental conditions, *viz.*, (1) the nature of the previous crop in the rotation, (2) the manure applied, (3) the cultural operations done during the season, and (4) the time of sowing the seed, all have a significant influence on the expression of the character". From his preliminary genetical studies of the sympodial habit in *G. arboreum* crosses, he found it to be quantitative in inheritance. The present authors are not aware of any further contributions on the subject. Some fresh information could be gathered in the course of an investigation undertaken on a plant having almost all sympodial branches. For various reasons, the inheritance studies have remained incomplete. But, the data collected together with data on the botanical aspects are presented in this paper.

The plant was observed in a F_4 progeny of 23 plants of the cross, (1 A. Long Boll* × *anomalum*) F_1 doubled × B.C. 1–2† × B.C. 1–2, raised in the 1952–53 season at the Agricultural Research Station, Surat. No such plant had been observed in the previous generations.

Description

As mentioned above, almost all the branches of the plant were sympodial as a result of which it looked open and sparse. Its leaves, bracts and bolls were small. The leaves were dark green and slightly curled upwards. All the seeds were very sparsely linted and some of them were hollow. On account of this, the bolls were only partially filled and somewhat hollow. However, the seeds were more fuzzy and belonged to the 8th grade (Hutchinson and Ramiah, 1938) while those of its monopodial sibs were of the 5th grade. The sympodial appearance was independent of the other special characteristics mentioned above except ginning outturn which was distinctly lower on

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[1] Present address: Central Tobacco Research Institute, Rajahmundry, South India.

* An old economic strain of the Agricultural Research Station, Surat, evolved by selection.

† A synthetic wilt (*Fusarium vasinfectum*) resistant strain under large-scale cultivation in the Broach tract of the Bombay State.

account of the sparse lint in sympodial looking plants. In segregates derived from the above described plant in the 1953–54 season, ginning outturn varied from 25·4–34·8 per cent. in plant with monopodial appearance while it ranged from 16·7 to 23·1 in those with sympodial appearance. Very similar distinctness was observed between their progenies in 1954–55 (*vide* Appendix). In the back cross F_2 progenies grown in 1954–55 which were all derived from normal parents the ginning percentage varied from 18·5 to 41·5 with the mode at 29·0, indicating that the distinctness was broken down due to the reinfusion of the blood of the high ginning (40 per cent.) B.C. 1–2.

The hollowness of some of the seeds may be due to the interspecific nature of the cross involving the A and B genoms. Other special characteristics except the sympodial appearance and sparse lintedness seemed to be of *anomalum* origin. On account of the limited facilities available, only the sympodial habit could be studied to a certain extent. The limited amount of data recorded are discussed in this article.

The classification for the sympodial habit was done by two different criteria, *viz.* (i) appearance of the plant which was recorded as sympodial when most of the main branches were sympodial, or monopodial when most of them were monopodial, (ii) whether the branching initiation was with a sympodium or a monopodium. The latter aspect included that studied by Harland, *i.e.*, the node number at which the first sympodium appeared. The first classification was done in both the 1953–54 and 1954–55 seasons. The second character was studied only in 1954–55 as the idea occurred only in that season. A number of plants get pruned early in the season due to the attack of larvæ of *Earias* sp. Since pruning affects branching initiation, the pruned plants had to be left out for purposes of observations on branching initiation.

The original sympodial looking plant was selfed and also backcrossed to B.C. 1–2 in 1952–53. From the selfed seed a progeny of 14 plants was raised in 1953–54. These plants were selfed in turn and 14 progenies consisting of 300 plants in all, of which 271 remained unpruned, were grown in 1954–55. The backcross gave, in 1953–54, 17 F_1 plants which were all monopodial in appearance. The selfed seed of 10 was sown for backcross F_2 in 1954–55 but data were recorded only on progenies derived from 8. The yearwise information on the basis of the above mentioned two criteria are given on next page.

Progenywise classification for all segregates including the pruned plants in the backcrossed line is given in Table I. Further, progenywise segregation for appearance and branching initiation in the selfed and backcrossed lines is given in Table II.

The data from only the backcrossed line can be depended upon for segregation ratios as the percentage of hollow seeds was less than 5 per cent. in that line.

Selfed line 1952–53

Sympodial

9 Sympodials — 1953–54 — 5 Monopodials

192 All Sympodials — 1954–55

77 Monopodials of which 70 classified for branching initiation

11 Sympodials of which 9 classified for branching initiation

Started branching with

Started branching with

Prog. No.	Sympodium	Monopodium
2152	6	1
2155	16	24
2157	1	2
2159	16	6
2160	19	17
2165	6	16
2166	18	21
2167	6	7
2169	6	4
	94	98

Started branching with			
Sympodium	Monopodium	Sympodium	Monopodium
9	61	4	5

Backcrossed line 1953–54

(B.C. 1-2 × Sympodial) F_1 — 17 plants, all monopodials of which only 10 were grown. Data were taken only on 8 for appearance in F_2

Backcross F_2 (Eight segregating progenies) 1954–55

102 sympodials (of which 74 unpruned plants)

257 monopodials (of which 145 unpruned plants)

Started branching with

Sympodium	Monopodium
18	56

Started branching with

Sympodium	Monopodium
15	130

TABLE I

Progenywise segregation for appearance for all segregates including the pruned plants in the Backcrossed F_2 line

Progeny No.	Monopodial	Sympodial	Total
2171	34	17	51
2173	40	22	62
2174	23	6	29
2176	44	14	58
2177	23	4	27
2180	49	18	67
2181	19	10	29
2183	25	11	36
TOTAL ..	257	102	359

The segregation for appearance both in individual progenies and on the whole conforms to a monogenic ratio, the X^2 for deviation being 2·23 and that for homogeneity for 7 d.f. being 7·22. The sympodial looking plants bred true to type in the subsequent generations. These results taken together with the fact that the original sympodial looking plant gave plants with both monopodial and sympodial appearance would tentatively suggest that sympodial appearance could be caused both by a recessive gene as well as by a gene epistatic to a dominant gene causing monopodial appearance.

It will be seen from the data of the backcrossed line in Table II that the ratio between plants with monopodial and sympodial appearance has been disturbed in the pruned plants. Pruning seems to have affected also the segregation for branching initiation. Therefore, no attempt is made to interpret the data for segregation in respect of either of the characters.

The node number at which branching initiation took place in the original sympodial plant in 1952–53 was not recorded. It was recorded in 1953–54 and was as below:—

1953–54

Mean node number at which the first sympodium appeared on sympodial segregates	12·30 ± 0·62
Mean node number at which the first sympodium appeared on normal segregates	15·20 ± 0·60
Mean node number at which the first monopodium appeared in B.C. 1–2	15·4 ± 0·47
Mean node number at which the first sympodium appeared in B.C. 1–2	20·5 ± 0·53
Mean node number at which the first sympodium appeared in (B.C. 1–2 × Sympodial) F_1—10 plants	13·40 ± 0·54
Lowest node number at which the first sympodium appeared in (B.C. 1–2 × Sympodial) F_1—10 plants	11
Highest node number at which the first sympodium appeared in (B.C. 1–2 × Sympodial) F_1—10 plants	16
Node number at which the first sympodium appeared in (Sympodial × B.C. 1–2) F_1—only one plant ..	8·0

In 1954–55, data were collected more fully in the selfed line in respect of the following points:—

(1) Mean node number at which branching started.

(2) Mean number of days between sowing and appearance of the first branch.

(3) Mean node number at which the first monopodium appeared on plants starting branching with a sympodium and *vice versa.*

(4) Mean number of days taken by plants with either type of branching initiation to put forth the first reverse type of branch as mentioned in (3) above.

In progenies of the backcrossed F_2 line only observation on (1) above could be taken. The data are summarised in Tables III to VI.

The strain, B.C. 1–2, is monopodial both in appearance as well as in branching initiation, the first sympodium appearing at about the 20th node. In the 10 F_1 plants resulting from the cross (B.C. 1–2 × Sympodial looking plant), the average node number at which the first sympodium appeared was lowered down to 13·4, the lowest being 11 and the highest 16. However, in the lone F_1 plant from the same cross with the sympodial looking plant as the seed parent, it was only 8·0. Thus, for the node number at which the first sympodial appears

TABLE II

Progenywise segregation according to appearance and branching initiation in the selfed and backcrossed lines

		Monopodial			Sympodial			
		Started branching with		Total	Started branching with		Total	Grand Total
		Monop.	Symp.		Monop.	Symp.		
Backcrossed line—								
F_2 Progeny No.	2171	20	3	23	8	1	9	32
	2173	25	1	26	17	2	19	45
	2174	17	4	21	3	1	4	25
	2176	24	1	25	7	2	9	34
	2177	8	0	8	1	3	4	12
	2180	14	2	16	9	3	12	28
	2181	10	3	13	6	2	8	21
	2183	12	1	13	5	4	9	22
	Total	130	15	145	56	18	74	219
	2182	Data from appearance not taken						22
	2184	do.						25
Selfed line—								
Progeny No.	2154	23	0	23	2	0	2	25
	2156	11	3	14	3	0	3	17
	2161	5	0	5	0	2	2	7
	2163	8	2	10	0	0	0	10
	2168	14	4	18	0	2	2	20
	Total	61	9	70	5	4	9	79

the F_1 seems to be intermediate, but more towards the parent producing the first sympodium at a lower node number as reported by Harland (1938).

TABLE III

Mean node numbers at which branching started (*Season*—1954–55)

Lineage	Parental appearance	Own appearance	No. of plants	Starting with monopodium (mean node No.)	No. of plants	Starting with sympodium (mean node No.)
Selfed line	Sympodial	Sympodial	94	9·90 ±0·17	98	8·70 ± 0·21
	Monopodial	Monopodial	61	8·0 ±0·39	9	9·7 ± 0·76
		Sympodial	5	9·0 ±1·13	4	11·7 ± 1·85
Backcrossed line (F_2)	Monopodial	Monopodial	130	8·4 ±0·27	15	12·5 ± 0·80
		Sympodial	56	9·3 ±0·35	18	11·7 ± 0·51
		Unclassified	43	8·1 ±0·33	4	12·0 ± 1·08

In the F_2 progeny of the backcrossed line, branching started at about the 8th or the 9th node in segregates which started with monopodia and at about the 11th or 12th node in those starting with sympodia; but, the node number at which the branching initiation took place was not influenced by the appearance of the plant, whether monopodial or sympodial.

The frequency distribution of plants according to the node number at which the first sympodial branch was produced was as given on next page.

In the selfed line of the sympodial, a clear difference is not noticed in the node number at which branching initiation takes place according to whether it starts with a monopodium or sympodium. It is to be observed in general that in plants starting with sympodia in the selfed line, the initial node number is lower than in similar plants in the F_2 progenies of the backcrossed line.

In Table IV are given data on the number of days taken for the initiation of branching in progenies of the selfed line grown in 1954–55.

It will be seen that plants starting branching with monopodia took about a week longer to produce the first branch than those starting branching with sympodia.

Node No.	No. of plants with Monopodial appearance	Sympodial appearance	
7	..	1	
8	5	3	
9	6	5	
10	7	3	
11	24	10	
12	27	12	
13	25	9	
14	16	10	
15	11	8	
16	7	7	
17	6	1	
18	4	3	
19	4	1	
20	2	..	
21	..	..	
22	..	..	
23	1	..	
24	..	..	
25	..	..	
26	..	..	
27	..	1	
TOTAL ..	145	74	= 219

TABLE IV

(a) Mean No. of days between sowing and appearance of the first branch

		Total No. of plants	Mean No. of days for 89 originally sown plants*	Total No. of plants	Mean No. of days for 84 originally sown plants*
Selfed line	Sympodial	94	66·30 ± 0·90	98	59·80 ± 0·58
	Monopodial	(——Data not available——)			

* Plants sown later for gap-filling have been left out for these observations.

(*b*) *Frequency distribution of plants according to the number of days taken for the first branch to appear*

Plants' habit	No. of days from sowing									Remarks
	57	61	75	79	83	87	92	107	Total	
Plants starting with monopodial branch	31	16	41	1	..	..	..	..	89	
Plants starting with sympodial branch	52	25	6	..	1	..	..	..	84	

The detailed data on the production of the first reverse type of branch in progenies derived from the selfed and the backcrossed lines are as given in Table V.

TABLE V

(*a*) *Mean mode number at which the first reverse type of branching appeared*, i.e., *at which first monopodium would appear on a plant starting with sympodium and* vice versa

Lineage	Parental appearance	Own appearance	No. of plants	Starting with sympodium (mean node No.)	No. of plants	Starting with monopodium (mean node No.)
Selfed line	Sympodial	Sympodial	94	12·00 ± 0·51	98	11·00 ± 0·16
	Monopodial	Monopodial	61	Not available	9	Not available
		Sympodial	5	do.	4	do.
Mean No. of days taken for the first reverse type of branch to appear						
Selfed line	Sympodial	..	94	83·40 ± 1·87	98	67·10 ± 0·95
	Monopodial	..	(—— Data not available ——)			

In lines having the sympodial appearance, the plants, whether they started with monopodia or sympodia, produced the first reverse type of branch almost at a similar node (11th or 12th); but, those starting with monopodia produced the first sympodium much earlier (about a fortnight on an average) than plants starting with sympodia produced the first monopodium.

With a view to see as to how pruning affects branching, 10 plants raised in pots were nipped prior to the production of the first branch

and 10 more, starting only with sympodia, immediately after the first branch appeared. The observations taken are given in Table VI.

(*b*) *Frequency distribution of plants according to the number of days taken for the first reverse type of branch to appear*

Plants' habit	No. of days from sowing									Remarks
	57	61	75	79	83	87	92	107	Total	
Appearance of first monopodial on plants starting with sympodial	..	10	22	2	3	8	7	14	66	Plants sown later for gap filling have been left out for these observations
Appearance of first sympodial on plants starting with monopodial	28	12	41	3	..	..	..	..	84	..

TABLE VI

Data showing the effects of pruning on branching (*plants were nipped artificially*)

Nature of pruning	No. of plants	Mean node No. at which the first branch appeared before pruning	Mean node No. at which the first branch appeared after pruning		Mean node No. up to which the monopodial branching extended downwards
			Sympodium	Monopodium	
Plants pruned prior to the appearance of the first branch	2	..	..	2·9±0·17	2·9
do.	8	..	7·0±0·0	..	..
Plants pruned immediately after the appearance of the first branch which was sympodium	10	6·9±0·22	..	4·1±0·41	4·0

The mean node number at which the first sympodial branch appeared in unpruned plants was unusually lower as the pots happened to be kept under shade. (In field plants raised in the sun it is about $12 \cdot 3 \pm 0 \cdot 62$; *vide* data of 1953–54.) The limited data would show that plants pruned before branching produced the first branch, in general, at a low node and much lower, if the initial branch were a monopodium.

Summary and Conclusions

The investigation was carried out on the selfed and backcrossed F_2 progenies of the sympodial looking plant found in a F_4 progeny of an interspecific cross involving *G. herbaceum* and *G. anomalum* parents. Observations were taken in respect of (i) monopodial or sympodial appearance of the plants and (ii) whether the branching was initiated with a monopodium or sympodium. The latter included also the node number at which the first sympodium appeared, which was the criterion adopted for branching habit by Harland (1938). In addition, the number of the node at which the first branch of either type appeared and the number of days taken therefor from sowing and similar observations on the emergence of the first reverse type of branch were recorded. The data collected are suggestive of the following:—

(1) The sympodial appearance seems to be caused both by a recessive gene as well as by a gene epistatic to the dominant gene causing monopodial appearance.

(2) Plants which were monopodial in appearance produced the first sympodial branch at a higher node than did those which were sympodial in appearance.

(3) The tendency to produce the first sympodium at a low node number appears to be partially dominant to that of producing it at a high node. However, the character seems to be polygenic.

(4) Plants initiating branching with a monopodium started at a lower (8th or 9th) node but took a week more therefor than those starting with a sympodium which started at a higher node (11th or 12th). The node of branching initiation does not appear to have been influenced by the appearance of the plant, whether monopodial or sympodial.

(5) Observations taken only on plants with a sympodial appearance show that they produced their first branch at a similar node (*i.e.*, about the 11th or 12th) irrespective of whether the branching initiation took place with a monopodium or sympodium. But, in these plants, those starting with a monopodium produced the first sympodium a fortnight earlier than those starting with sympodium produced the first monopodium.

(6) From the small amount of data collected it is observed that pruning of the plant before branching resulted in the production of the first branch at a low node. The node of start was much lower, if the initial branch were to be a monopodium.

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Appendix

Frequency distribution of ginning outturn in 1954–55 *of plants in progenies derived from selfed sympodial and normal looking segregates of* 1953–54

Ginning per cent.	Appearance (1953–54)—	Sympodial	Sympodial	Sympodial	Sympodial	Normal	
	Progeny No.—	2155	2160	2165	2166	2168	
	Appearance in 1954–55—	All Symp.	All Symp.	All Symp.	All Symp.	Normal	Sympod.
15·6–16·5		1	..	..	..	..	..
16·6–17·5		3	..	..	1	..	..
17·6–18·5		4	1	1	4	..	..
18·6–19·5		5	3	..	4	1	0
19·6–20·5		5	1	1	6	..	..
20·6–21·5		2	8	..	8	..	..
21·6–22·5		2	5	2	1	..	..
22·6–23·5		4	7	2	2	..	..
23·6–24·5		6	4	3	5	..	..
24·6–25·5		3	3	3	3	..	..
25·6–26·5		..	2	5	..	1	1
26·6–27·5		..	1	1	..	3	0
27·6–28·5		..	..	..	..	2	1
28·6–29·5		..	..	..	1	3	0
29·6–30·5		..	..	1	..	2	0
30·6–31·5		..	..	..	2	2	0
31·6–32·5		..	..	1	..	3	0
32·6–33·5		..	..	..	..	0	1
33·6–34·5		..	..	..	..	3	0
Total ..		35	35	20	37	20	3

CYTO-TAXONOMIC STUDIES IN THE GENUS *RICCIA* (MICH.) L.

II. *R. crystallina* L. and *R. cruciata* Kash.*

By Narinder Chopra§ and Ram Udar

Department of Botany, Lucknow University, Lucknow

(Received for publication on July 30, 1957)

Introduction

In an earlier communication Udar and Chopra (1957) described the cytology of *Riccia billardieri* Mont. *et* N. and *R. gangetica* Ahmad and they observed the latter to be a hexaploid ($n = 24$) species, the number $n = 24$ being the first report for any species of the genus *Riccia*. In view of this interesting observation Dr. S. K. Pandé suggested to the authors to pursue the cytotaxonomy and cytogeography of the various species of *Riccia* growing in India in order to arrive at certain definite conclusions about the fascinating aspect of the interspecific relationships in the genus.

The present contribution deals with the cytology of *R. crystallina* and *R. cruciata*, the two closely related species belonging to the section Ricciella of the genus and growing abundantly in practically all parts of the country during the winters quite often intermingled in nature.

Material and Methods

The specimens of *R. crystallina* and *R. cruciata* were collected from the Experimental Farm and the Botanical Garden of the Department and also from the compound of the local I. T. College. Plants maintained under culture were also utilized. All chromosome counts are based on the squash method in which acetic-alcohol (1 : 3) and aceto-carmine were used as fixative and staining agent respectively. For mitotic number the tips of the young thalli were squashed and for meiotic study complete young capsules were isolated from the thalli and were squashed.

Observations

Riccia crystallina L.

In several aceto-carmine thallus squashes 8 chromosomes were counted at metaphase (Fig. 1). Three of these were V-shaped and the rest are more or less rod-like.

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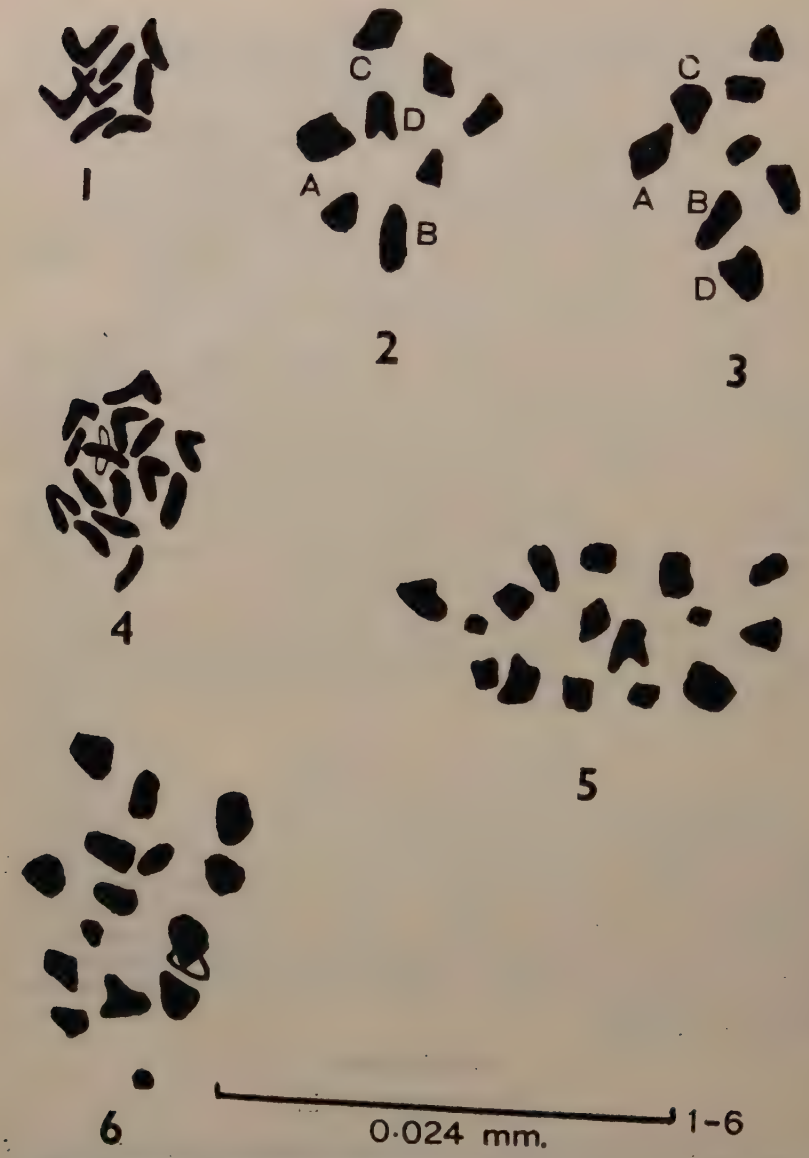
* Contribution from the Department of Botany, Lucknow University, India, New Series, No. 28.

§ Present address: Birbal Sahni Institute of Palæobotany, Lucknow.



TEXT-FIGS. 1–6. FIGS. 1–3. *Riccia crystallina* L. Fig. 1. 8 chromosomes at metaphase from thallus apex. Figs. 2, 3. 8 chromosomes (bivalents) at metaphase I. Figs. 4–6. *Riccia cruciata* Kash. Fig. 4. 16 chromosomes at metaphase from thallus apex. Figs. 5 and 6. 16 bivalents at metaphase I.

In several capsule squashes 8 bivalents were counted at diakinesis. Four of them, *i.e.*, A, B, C and D are larger; B being rod-shaped and D showing cross-chiasma while the rest are middling in size and

show relatively no morphological differentiation at diakinesis and metaphase I (Figs. 2, 3). Meiosis is normal.

Riccia cruciata Kash.

In several aceto-carmine thallus squashes 16 chromosomes were counted at metaphase (Fig. 4). Six of these are V-shaped and the rest more or less rod-like and approximately equal in size.

In several aceto-carmine capsule squashes 16 bivalents were counted at metaphase I (Figs. 5, 6). Two of these are conspicuously small in relation to others while 5 are larger and the rest intermediate in size. Meiosis is normal.

Discussion

From a study of the genus *Mnium*, Heitz (1942) and Lowry (1948) pointed out that a strong correlation exists between bisexuality and polyploidy. Subsequently Lowry (1954) observed a similar correlation to be true in the case of the genus *Atrichum* as well. Such a generalization seems to be reasonably applicable in the genus *Riccia*.

From a study of two monœcious species Udar and Chopra (1957) reported $n = 8$ and $n = 24$ for *R. billardieri* and *R. gangetica* respectively. The chromosome count and the morphology in *R. gangetica* strongly favour the assumption that its possible ancestor is some species with $n = 8$ from which a race A originated with $n = 16$ by chromosome doubling. The present-day *R. gangetica*, in all probability, is a hybrid having the parent A with $n = 16$ and another parent with $n = 8$ both possibly being monœcious. This hexaploid *R. gangetica* breeds true for the monœcious characters.

In *R. cruciata*, apparently an endemic species, two small bivalents were counted at diakinesis but at mitotic metaphase the authors failed to find any conspicuously small chromosome and a bigger complement which would have led to the speculation about the origin of this species from a diœcious ancestor. Evidently in view of the absence of any sex-determinant in this species it could safely be concluded that the origin of *R. cruciata* is from some monœcious ancestor by chromosome doubling and through several generations the tetraploid *R. cruciata* got stabilized and breeds true for monœcious characters. In view of the close association of *R. cruciata* with R. *crystallina* in nature and broad similarities in taxonomic features in the two species with relatively minor but constant variations (see table below) its ancestor, in all probability, is the monœcious *R. crystallina*.

From the foregoing discussion it is evident that the monœcious hexaploid *R. gangetica* originated by chromosome doubling and hybridization with the species with $n = 8$ and the tetraploid *R. cruciata* originated by chromosome doubling.

	R. crystallina	*R. cruciata*
SEXUALITY	Monœcious	Monœcious
HABIT ..	Usually form well-defined rosettes	Usually form cruciate thalli (due to suppression of dichotomy)
THALLUS ..	Crystalline in appearance with broad air-chambers	Comparatively more compact with smaller air-chambers
SPORE ..	Winged, tetrahedral, 60–85 μ in the maximum diameter with large often incomplete reticulations across the outer face	Winged, tetrahedral, 50–60 μ in the maximum diameter, 4–5 large pentagonal reticulations across the outer face

Summary

1. *R. crystallina* is monœcious with $n = 8$ and $2n = 16$.

2. *R. cruciata* is monœcious with $n = 16$ and $2n = 32$. This tetraploid species has originated by chromosome doubling and its probable ancestor is *R. crystallina*.

3. The ancestry of *R. gangetica*, a hexaploid species with $n = 24$, has been discussed. It has been suggested that it has originated from a species by chromosome doubling and hybridization.

Acknowledgments

The authors are grateful to Dr. S. K. Pandé, D.Sc., for his keen interest and valuable guidance in the preparation of this paper.

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* Not seen in original.

CYTOLOGICAL STUDIES IN INDIAN MOSSES[1]

II. *Physcomitrellopsis indica* Dix., *Anomodon minor* (P. Beauv.) Furnr. and *Bartramia subpellucida* Mitt.

By S. K. Pandé and Narinder Chopra[2]

(*Department of Botany, University of Lucknow, India*)

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Introduction

In an earlier publication, dealing with the cytology of four Indian mosses, Pandé and Chopra (1957) critically reviewed the literature on the cytological investigations in mosses. They reported the sex determinants in two species from India, *i.e.*, *Pogonatum stevensii* Ren. and Card. and *Bryum nitens* Hook.

The present contribution deals with the cytology of *Physcomitrellopsis indica* Dix., *Anomodon minor* (P. Beauv.) Furnr. and *Bartramia subpellucida* Mitt.

Material and Method

Physcomitrellopsis indica Dix. is one of the most common winter mosses growing in and around Lucknow (398 ft. above sea-level) from November to March. The material for the present study of this species was collected from the compound of the historic Residency building and Dilkusha Garden, while the specimens of *Anomodon minor* (P. Beauv.) Furnr. and *Bartramia subpellucida* Mitt. were collected from Mussoorie (6,500 ft. above sea-level), where these species grow luxuriantly during the monsoon months. Acetic-alcohol and propionic-alcohol (1 : 3) were used as fixatives. Aceto-carmine and propionic-carmine squash methods were employed and the temporary slides were made permanent in the usual way. For antheridial squashes propionic-alcohol as fixative and propionic-carmine as the stain, gave most satisfactory results.

Observations

1. *Physcomitrellopsis indica* belongs to the family *Funariaceæ*. In several aceto-carmine capsule squashes 31 bivalents were counted at metaphase I (Text-Figs. 1–2). Meiosis is normal.

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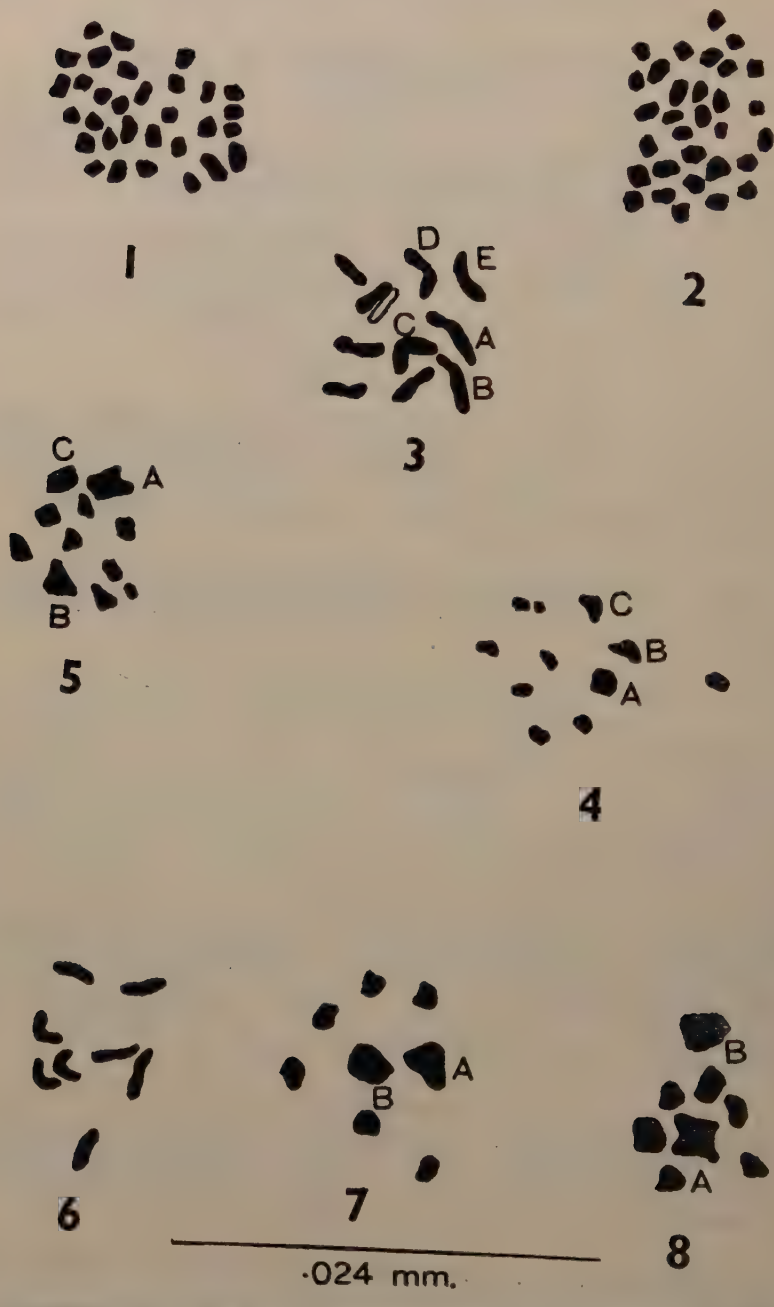
[1] Contribution from the Botany Department, University of Lucknow, New Series No. 27.

[2] Birbal Sahni Institute of Palæobotany, Lucknow.



TEXT-FIGS. 1–8.—Figs. 1–2. *Physcomitrellopsis indica* Dix.—31 bivalents at metaphase I. Figs. 3–5. *Anomodon minor* (P. Beauv.) Furnr.—Fig. 3. 11 chromo-

somes at metaphase in the spermatogenic cells. Fig. 4. 11 bivalents in diakinesis. Fig. 5. 11 bivalents at metaphase I. Figs. 6–8. *Bartramia subpellucida* Mitt.— Fig. 6. 8 chromosomes at metaphase in the spermatogenic cell. Fig. 7. 8 bivalents at diakinesis. Fig. 8. 8 bivalents at metaphase I.

Griesinger (1937) (see Vaarama, 1953) reported $n = 26$ for *Funaria mediterranea*. For *Funaria hygrometrica* Hedw. Wettstein (1923) (see Vaarama, 1953) reported $n = 14$ for central European material. Vaarama (1950 *a*) gave $n = 28$ for wild Finnish material of the same species while, for Californian material, he (Vaarama, 1953) reported $n = 14$.

Thus it is obvious from the chromosome counts of *Funaria hygrometrica* that, in addition to a diploid race, it has also a tetraploid race. For *Funaria californica* Sull. and Lesq. Vaarama (1953) reported $n = 24$ while for *Funaria microstoma* Br. and Sch. var. *obtusifolia* Grout $n = 28$ has been reported by Steere (1954).

Evidently, as will be seen from the chromosome counts reported, in the genus *Funaria*, an exact interspecific polyploid series does not exist. Pandé and Chopra (1957 *a*) reported $n = 9$ for *Physcomitrium pyriforme* while in *Physcomitrellopsis indica* the haploid number is 31. Thus, there is no cytological inter-generic relationship whatsoever among the genera of the family Funariaceæ which have been investigated so far.

2. *Anomodon minor* (P. Beauv.) Furnr. belongs to the family Thudiaceæ. In several propionic-carmine antheridial squashes 11 chromosomes were counted at metaphase. Two of the chromosomes, *i.e.*, A and B are comparatively larger than the other nine and show terminal attachment. Among the remaining nine chromosomes, three, *i.e.*, C, D and E exhibit median while six have subterminal attachment (Text-Fig. 3).

In aceto-carmine capsule squashes of *A. minor* 11 bivalents were counted at diakinesis and metaphase in a number of preparations. Three of these, *i.e.*, A, B and C are larger than the remaining eight in descending order. Among the latter, one bivalent is very small (Text-Figs. 4, 5). Meiosis is normal.

3. *Bartramia subpellucida* Mitt. belongs to the family *Bartramiaceæ*. In several propionic-carmine antheridial squashes eight chromosomes were counted at metaphase. Three of these are V-shaped while five are rod-like (Text-Fig. 6).

In aceto-carmine capsule squashes 8 bivalents were counted at diakinesis and metaphase I. Two of the bivalents as compared to other six are larger in size (Text-Figs. 7–8). Meiosis is normal.

Conclusions

Shimotomai and Koyama (1932) reported $n = 10$ for *Thudium japonicum*, Yano (1951) reported $n = 10$ for *Thudium micropteris*,

T. viridiforme, *T. uliginosum* while Steere (1954) reported $n = 11$ for *Thudium recognitum*. Yano (1951) reported $n = 11$ for two species of *Anomodon*, *i.e.*, *A. apiculatus* Br. Cur and *A. rostratuo* (Hedw.) Schimp. and *Claopodium* sp.

From the accompanying table it will be evident that the basic number for the genera *Thudium*, *Anomodon* and *Claopodium* is 10, 11, 11 respectively. In all probability $n = 11$ in *Thudium recognitum* is due to aneuoploidy from the parent stock with $n = 10$ which is stable and common in the various species of the genus *Thudium* which have been so far worked out. In the genus *Anomodon*, however, $n = 11$ is apparently well established though the chances to find species with $n = 10$ should not be ruled out. It will be worthwhile to pursue an extensive cytological study in the genera *Thudium*, *Anomodon* and *Claopodium*.

Both Vaarama (1950) and Steere (1954) found $n = 12$ in *Bartramia ithyphylla* Brid. from the Finnish and Arctic Alaskan material respectively. Steere reported that though normal meiosis was the rule, in rare cases, laggards were observed. In the study of *Bartramia subpellucida* from Mussoorie the authors did not find any laggards. For *Bartramia pomiformis* Hedw. according to Heitz (1928) (see Lowry, 1954) n=7–8 for the German material. Kurita (1937) (see Lowry, 1954) reported $n = 8$ for Japanese material, while for *B. pomiformis* Hedw. var. *crispa* (Web. & Mohr.) B. & S. from Finland, Vaarama (1950) reported $n = 8$. The same number has been given by Lowry (1954) for Michigan material also. According to Steere (1954) in *Conostomum tetragonum* $n = 16$.

It would appear from the study of the chromosome number in the genus *Bartramia* (see table given below) that the basic number for this genus may be 4 as has also been pointed out by Vaarama (1950), Lowry (1953) and Steere (1954). If this is confirmed, then *B. pomiformis*, *B. subpellucida*, the tetraploids, and *B. ithyphylla*, a hexaploid, originated in the speciation of the genus *Bartramia* from a parent stock having $n = 4$.

The following is the table of the chromosome number in families *Funariaceæ*, *Thudiaceæ and Bartramiaceæ*.

Name of the family and th e plant	*n*	2*n*	Author and the year
Family *Funariaceæ*			
Genus *Funaria*			
F. hygrometrica ..		14″	Wettstein (1924)
F. hygrometrica ..	14	14″	Vaarama (1953)
F. hygrometrica ..		28″	,, (1950)
F. californica		24″	,, ,,
F. mediterranea ..		26″	Griesinger (1937)
F. microstoma var. *obtusifolia* ..		28″	Steere (1954)

Name of the family and the plant	*n*	2*n*	Author and the year
Genus *Physcomitrium*			
P. pyriforme	9	9″	Pandê and Chopra (1957)
Genus *Physcomitrellopsis*			
P. indica		31″	Present paper
Family *Thudiaceæ*			
Genus *Thudium*			
T. micropteris ..		10″	Yano (1951)
T. viridiforme ..		,,	,,
T. uliginosum ..		,,	,,
T. japonicum ..		,,	Shimotomai and Koyama (1932)
T. recognitum ..		11″	Steere (1954)
Genus *Anomodon*			
A. apiculatus		11″	Yano (1951)
A. rostratus		11″	Yano (1951)
A. minor	11	,,	Present paper
Genus *Claopodium*			
C. sp.		11″	Yano (1951)
Family *Bartramiaceæ*			
Genus *Bartramia*			
B. ithyphylla		12″	Steere (1954)
,, ...		12″	Vaarama (1950)
B. pomiformis ..		7–8″	Heitz (1928)
,, ...		8″	Kurita (1937)
,, var. *crispa*		8″	Vaarama (1950)
B. subpellucida ..	8	8″	Present study
Genus *Conostomum*			
C. tetragonum ..		16″	Steere (1954)

Acknowledgments

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ANEUPLOIDY IN SPECIES HYBRID OF *ARACHIS*

By L. S. S. Kumar and R. D'Cruz

Botany Section, College of Agriculture, Poona

(Received for publication on October 16, 1957)

Kumar *et al.* (1957) have described certain important characters of *Arachis hypogæa* ($2n = 40$, Fig. 8), *A. villosa* var. *correntina* ($2n = 20$, Fig. 9) and of the triploid hybrid between these two species.

The hybrid having a somatic complement of 30 chromosomes (Fig. 10) was backcrossed to *A. hypogæa*. From numerous reciprocal crosses made between *A. hypogæa* and the F_1 (*A. hypogæa* × *A. villosa*), only one cross was found to be successful in which *A. hypogæa* was the female parent.

This backcross hybrid plant (Fig. 4) had spreading habit like its wild parent *A. villosa* (Fig. 2) and the triploid parent (Fig. 3), while on the other hand, it was an annual resembling the cultivated parent *A. hypogæa* (Fig. 1). However, unlike its hybrid parent, this new plant was fertile and produced numerous seeds, intermediate in size (Fig. 7) as compared to those of *A. hypogæa* and *A. villosa* (Figs. 5 and 6).

Cytological examination of the pollen-mother-cells of this new plant revealed that the chromosomes at metaphase I mostly formed $1_{III} + 19_{II}$ (Fig. 11) and rarely $20_{II} + 1_{I}$ (Fig. 12). The new plant, therefore, was an aneuploid of the trisomic type with $2n + 1 = 41$ chromosomes. This aneuploid might have resulted from the abnormal distribution of chromosomes during the formation of gametes in one of the parents, probably in the triploid.

The details of the habit and chromosomal behaviour of the two species involved in the original cross, their hybrid and the new aneuploid plant are given in Table I.

Aneuploidy in *Arachis* was first reported in 1936 by Husted (quoted from Mendes, 1947), in a single plant of *A. rasteiro*. He observed a somatic complement of 41 chromosomes + 1 fragment. That aneuploid was, however, different from the one reported in this paper as it was derived from a single plant species, *viz.*, *A. rasteiro* and in addition to one chromosome, it also had a fragment, while the trisomic

TABLE I

Characteristics of the two species of Aachis, *their hybrid and of the aneuploid*

	Habit		No. of chromosomes	Meiotic behaviour	Seed	
	Growth	Duration			Size	Setting
A. hypogæa ..	Erect	Annual	40	20_{II}	Large	Normal
A. villosa var. *correntina*	Spreading	Perennial	20	10_{II}	Small	Low
Triploid hybrid	do.	do.	30	$10_{II}+10_{I}$	..	..
Aneuploid (Trisomic)	do.	Annual	41	$1_{III}+19_{II}$ or $20_{II}+1_{I}$	Medium	Normal

aneuploid reported here, showed no fragments and was synthesized from crosses involving two distinct species of *Arachis* as shown below:—

A. hypogæa ($2n = 40$) × *A. villosa* var. *correntina* ($2n = 20$)

↓

F_1 (*A. hypogæa* × *A. villosa*) × *A. hypogæa* ($2n = 30$) ($2n = 40$)

↓

New Aneuploid type ($2n + 1 = 41$)

The chromosome complements of the two species of *Arachis* involved in the securing of the aneuploid not only differ in chromosome number [*A. hypogæa* ($2n = 40$) and *A. villosa* var. *correntina* ($2n = 20$)] but as shown by Mendes (1947) and Krapovickas and Rigoni (1951), their individual chromosomes also differ in morphology and size. Further studies on the interrelationship of these two species of *Arachis* with other species both described and undescribed are in progress.

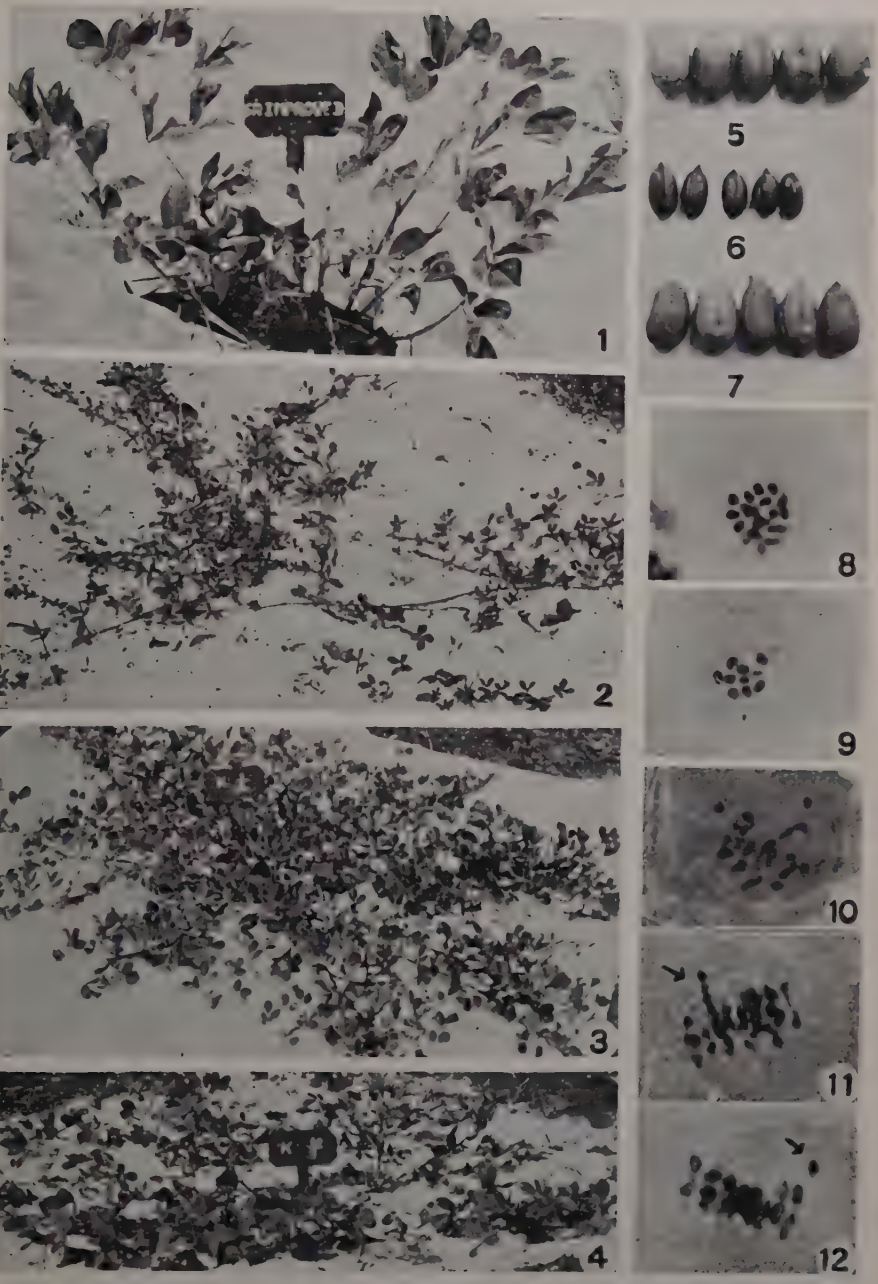
The cytological technique used in making smears of the pollen-mother-cell was the one described by McClintock (1929).

SUMMARY

The paper describes the occurrence of an aneuploid type of *Arachis* with $2n + 1 = 41$ chromosomes, which was obtained in a backcross involving interspecific hybridization.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the assistance rendered by Shri A. S. Jadhav.



L. S. S. Kumar & R. D'Cruz

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Explanation of Plate XIX

FIG. 1. *A. hypogæa.*

FIG. 2. *A. villosa.*

FIG. 3. Hybrid of the cross *A. hypogæa* × *A. villosa* var. *correntina.*

FIG. 4. Aneuploid derivative of the backcross *A. hypogæa* × F_1 (*A. hypogæa* × *A. villosa*)

FIG. 5. Seeds of *A. hypogæa.*

FIG. 6. Seeds of *A. villosa* var. *correntina.*

FIG. 7. Seeds of Aneuploid plant.

FIG. 8. Metaphase I in *A. hypogæa.*

FIG. 9. Metaphase I in *A. villosa* var. *correntina.*

FIG. 10. Metaphase I in triploid hybrid.

FIG. 11. Metaphase I in the aneuploid showing a trivalent.

FIG. 12. Metaphase I in the aneuploid showing an univalent.

ABNORMAL POLLEN GRAINS IN SOME INDIAN GYMNOSPERMS WITH REMARKS ON THE SIGNIFICANCE OF THE ABNORMALITIES

By Vishnu-Mittre*

Birbal Sahni Institute of Palæobotany, Lucknow (India)

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Introduction

Abnormal pollen grains in both the fossil and living gymnosperms have been described from time to time by various workers. Recently Lakhanpal and Nair (1956) have tabulated the list of the conifers belonging to winged-grained Abietineæ which are known to have produced abnormal pollen grains. The list though exhaustive does not include *Abies balsamifera* in which Wodehouse (1935, p. 264) has reported 3–4-winged abnormal pollen grains. Van Campo-Duplan (1950, pp. 52–59, 142, 144) has described abnormal pollen grains in several interspecific and intergeneric hybrids of Abietineæ such as *Pinus coulteri*, *Cedrus Libani*, *Picea Wilsonii*, *Picea Balfouriana*, *Pinus Thunbergii*, *Abies Delavayi*, *Abies Bornmuleriana* and *Abies Vilmorini*, etc.

Besides Pinaceæ abnormal pollen grains are also known in some members of the Cupressaceæ, Taxodiaceæ, Podocarpaceæ, Ephedraceæ and Gnetaceæ (Thomson, 1908; Wodehouse, 1935; Cranwell, 1940; Van Campo-Duplan, 1950). Besides variations in the number of wings in the winged grains, presence of aperture(s) on the non-aperturate grains, presence of wings on the unwinged pollen grains and variations in the exine pattern, size and form of the grains are some of the occasionally described abnormalities of the gymnospermous pollen grains. So far no abnormal pollen grains are described in the Cycadaceæ, Ginkgoaceæ and Araucariaceæ.

Amongst the fossil podocarps 1–4-winged abnormal pollen grains are known in *Masculostrobus Sahnii* (Vishnu-Mittre, 1956) a Jurassic male cone described from India.

Variable or abnormal pollen grains in Indian gymnosperms besides those listed by Lakhanpal and Nair (*loc. cit.*) are described by Johri (1948) in *Cedrus deodara* and Maheshwari (1935), Mulay and Khubchandani (1944) and Mulay and Nair (1952) in *Ephedra foliata*. Varia-

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* Now at Sub-Department of Quaternary Research, Botany School, Cambridge, U.K.

tions in size in the polyploid forms of *Ephedra* are described by Mehra (1947).

The observations noted here are chiefly based upon the Indian gymnosperms some of which are indigenous and the others cultivated in the gardens. The fresh material was collected by Prof. G. Erdtman, Dr. R. N. Lakhanpal and the author from the Botanical Gardens at Bangalore and Ootacamund and by the author and the Herbarium Assistant, Mr. B. D. Sharma from the Lloyd Botanic Gardens, Darjeeling, and from the Indian Botanic Gardens, Calcutta. The preserved material has been collected by the author and Mr. B. D. Sharma from the Herbaria of the Lloyd Botanic Gardens, Darjeeling, the Bengal Forest School, Kurseong and the Botany Department, Calcutta University. The author is extremely grateful to the Curator, L.B.G., Darjeeling, Director, B.F.S. Kurseong and Prof. I. Banerji for their kind permission to collect material from their herbaria. My thanks are due to Dr. R. N. Lakhanpal for suggesting improvements in the text.

Method.—The pollen slides are prepared by the method of acetolysis (Erdtman, 1952). Chlorination has been done in some preparations. Measurements given here are the averages of 10 pollen grains.

Observations

PINACEÆ

1. **Pinus** L.

Abnormal pollen grains in the genus *Pinus* are known in *P. Wallichiana*[1] (*P. excelsa*) (Puri, 1945), *P. tuberculata* (Wodehouse, 1935; p. 258) and *P. insularis* (*P. Khasya*), *roxburghii* (*longifolia*) and *Merkussii* (Chatterji, 1943), and in the fossil state in *P. sylvestris* (Florin, 1936, p. 638) and *P. strobus* (*resinosa*) (Wilson and Webster, 1944, p. 183). Recently abnormal pollen grains are observed in *P. insularis*, *P. roxburghii*, *P. sylvestris* and *P. densiflora*. Besides the already reported abnormal 3-winged pollen grains in *P. insularis* and *P. roxburghii* (Chatterji, *loc. cit.*). I have found certain additional abnormalities in the number and nature of wings in the grains of these two species.

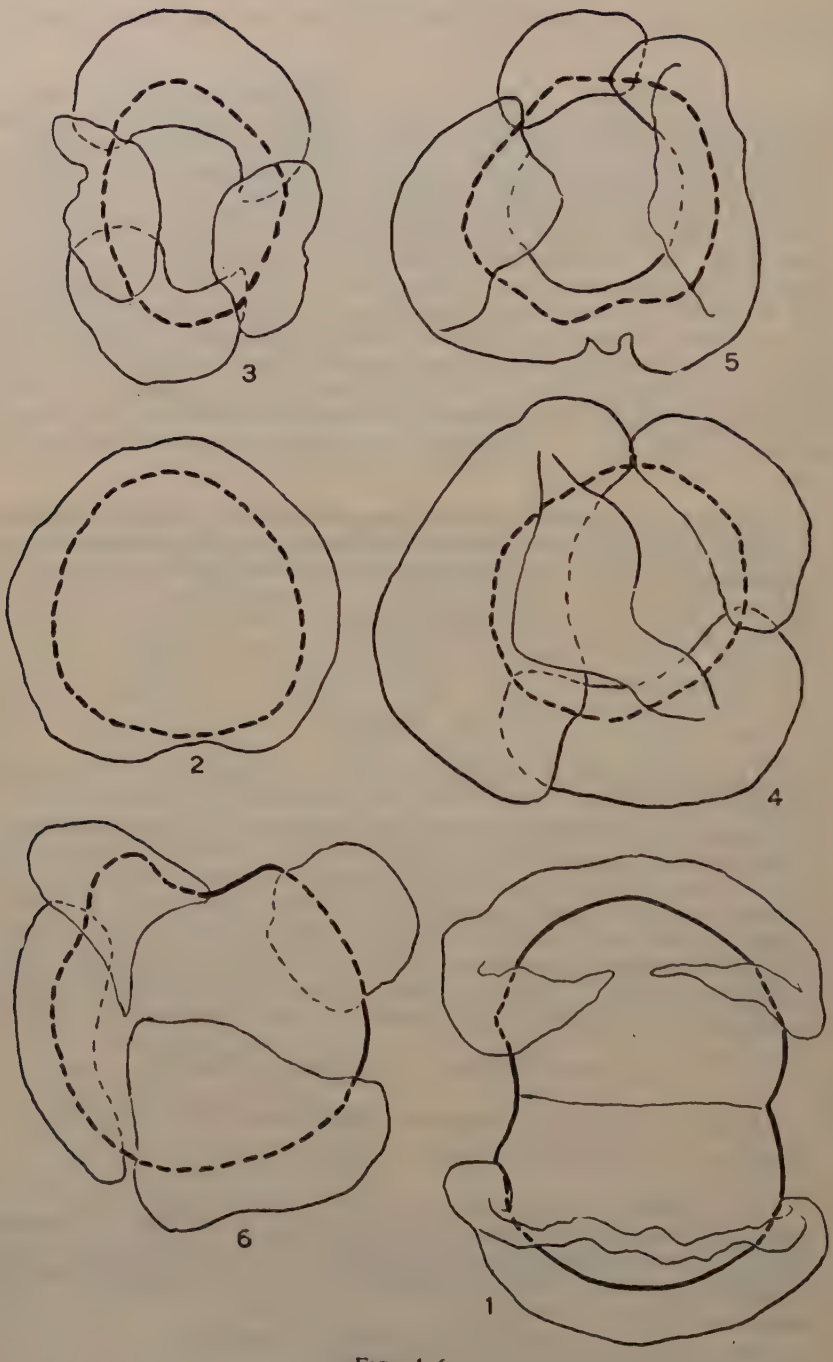
(i) *Pinus insularis* Endl. (*P. khasia* Royle)

Material.—L.B.G., Darjeeling, V-Mittre and B. D. Sharma, 1957.

(Pl. XX, Figs. 1–6; Text-Figs. 1–6)

The pollen grains are in all essential character as described by Van Campo-Duplan (1950) but are slightly smaller in size. The normal pollen grains are two-winged and measure $48 \times 22 \cdot 4\,\mu$ in size (including wings). There are a few giant grains about $56–60 \times 38 \cdot 4–45\,\mu$ in size

[1] The change in nomenclature is according to Bor (1953).



FIGS. 1-6.

TEXT-FIGS. 1–6. *Pinus insularis*. Fig. 1. A diad with one of the grains with a single bladder encircling the distal face of the body, ×600. Fig. 2. A grain with a single bladder and with a notch, ×600. Fig. 3. A grain with 4 bladders; two smaller attached at a level upper than the two larger ones, ×600. Fig. 4. A grain with four unequal wings, one of the wings is attached on the distal pole, ×600. Fig. 5. A grain with two unequal wings, the larger wing with two projecting lobes, ×600. Fig. 6. A grain with four unequal wings two attached on one face and two on the opposite face of the body, ×600.

including wings (Pl. XX, Fig. 6). Besides a few deformed tetrads there are some diads, about 65 μ along the longest diameter, in which the pollen grains are joined rather fused along their proximal faces (Pl. XX, Figs. 1–3, Text-Fig. 1). The individual grains in these diads are two-winged, occasionally in some the two-wings seem to have fused to form a single wing, encircling the distal face (Pl. XX, Fig. 3, Text-Fig. 1). In some of these diads a line of division is clearly noted between the grains though they are still united in the diad condition.

The abnormal pollen grains, about 57–60 μ in diameter, and 1–4-winged. Text-Fig. 2 shows a one-winged grain with a single bladder encircling the body and having a notch at one end. The pollen grain shown in Pl. XX, Fig. 4; Text-Fig. 5 has two unequal wings the larger one forming two lobes raised above. Text-Fig. 4 shows a 4-winged grain where besides the three unequal the fourth one is attached on the distal face. Text-Fig. 3 shows another 4-winged grain in which the two smaller wings are not attached at the same level with the body as the two larger ones, Pl. XX, Fig. 6. Text-Fig. 6 shows another 4-winged grain with the wings attached at different levels of the body. The wings in this grain are also unequal in size.

(ii) *Pinus roxburghii* Sarg. (*P. longifolia* Roxb.)

Material.—Herb. L.B.G., Darjeeling, G. Bahadur, 1950, Darjeeling.

Herb. L.B.G., Darjeeling, Sikkim Himalayas.

(Pl. 1, Figs. 7, 8)

The pollen grains are in all essential characters as described by Van Campo-Duplan (1950, p. 81) but are comparatively smaller in size. The normal pollen grains are 2-winged and are 36·8–43·3 × 22·4 –24·0 μ including wings. Diads as noted in *P. insularis* are also noted in this species though they are smaller in size than those of the normal 2-winged grains (Pl. XX, Fig. 7). The abnormal pollen grains are 1–4 winged. In some grains it appears as if an additional wing is present on the distal pole also. A few pollen grains show wings on both the poles. The pollen grain shown in Pl. XX, Fig. 8 has two unequal bladders, the larger showing two lobes.

In the above two species *P. insularis* and *P. roxburghii* pollen slides in 50% glycerine were also made of the individual cone-scales from different regions of the male cones. It was found that comparatively more abnormal pollen grains were found in the sporangia from

the apical regions of the cones than from the middle or the proximal regions.

(iii) *Pinus densiflora* Siebold et Zuccarini

Material.—L.B.G., Darjeeling, V-Mittre and B. D. Sharma, 1957.

(Pl. XX, Figs. 9–13; Text-Figs. 7–12)

The pollen grains are as described by Van Campo-Duplan (1950, p. 77) but are comparatively smaller in size. Normal pollen grains are 2-winged and measure $43 \cdot 2 \times 22 \cdot 4 \mu$ in size including wings. The body of the grains measuring $27 \cdot 2 \times 22 \cdot 4 \mu$ is ovoid in shape; in lateral view it looks triangular. The wings are smaller than the body. A few grains have wings larger than the body.

The abnormal pollen grains are 1–4-winged upto about 50μ in size. In some 2-winged grains the two wings are fused at one of the lateral faces (Pl. XX, Figs. 9, 11; Text-Fig. 10). A one-winged grain is seen in Pl. XX, Fig. 10; Text-Fig. 7. Text-Fig. 8 shows a 2-winged grain with two unequal wings each with two lobes projected up at the free ends. Text-Fig. 9 is again a 2-winged grain with unequal wings but devoid of free lobes. Text-Fig. 12 shows a 3-winged pollen grain with unequal wings. Pollen grain in Pl. XX, Fig. 12 shows besides three wings, an additional fourth wing also. Text-Fig. 11 shows a grain as in Text-Fig. 10 but with an additional wing on the distal pole. A 4-winged grain is seen in Pl. XX, Fig. 13.

(iv) *Pinus sylvestris*, L.

Material.—Herb., Univ. Bot. Dept., Calcutta, Banerji, 1940.

L.B.G., Darjeeling, V-Mittre and B. D. Sharma, 1957.

In essential characters the pollen grains of *P. sylvestris* are as described by previous workers (Erdtman, 1943, p. 140; Van Campo-Duplan, 1950, pp. 87–88).

The material collected in 1940 shows the pollen grains to be $35 \cdot 2 \times 17 \cdot 6 \mu$ while the material collected in 1957 shows the pollen grains to be $27 \cdot 6 \times 19 \cdot 2 \mu$. The pollen grains are comparatively much smaller than those described by other workers (Erdtman, *loc. cit.*).

2. Abies L.

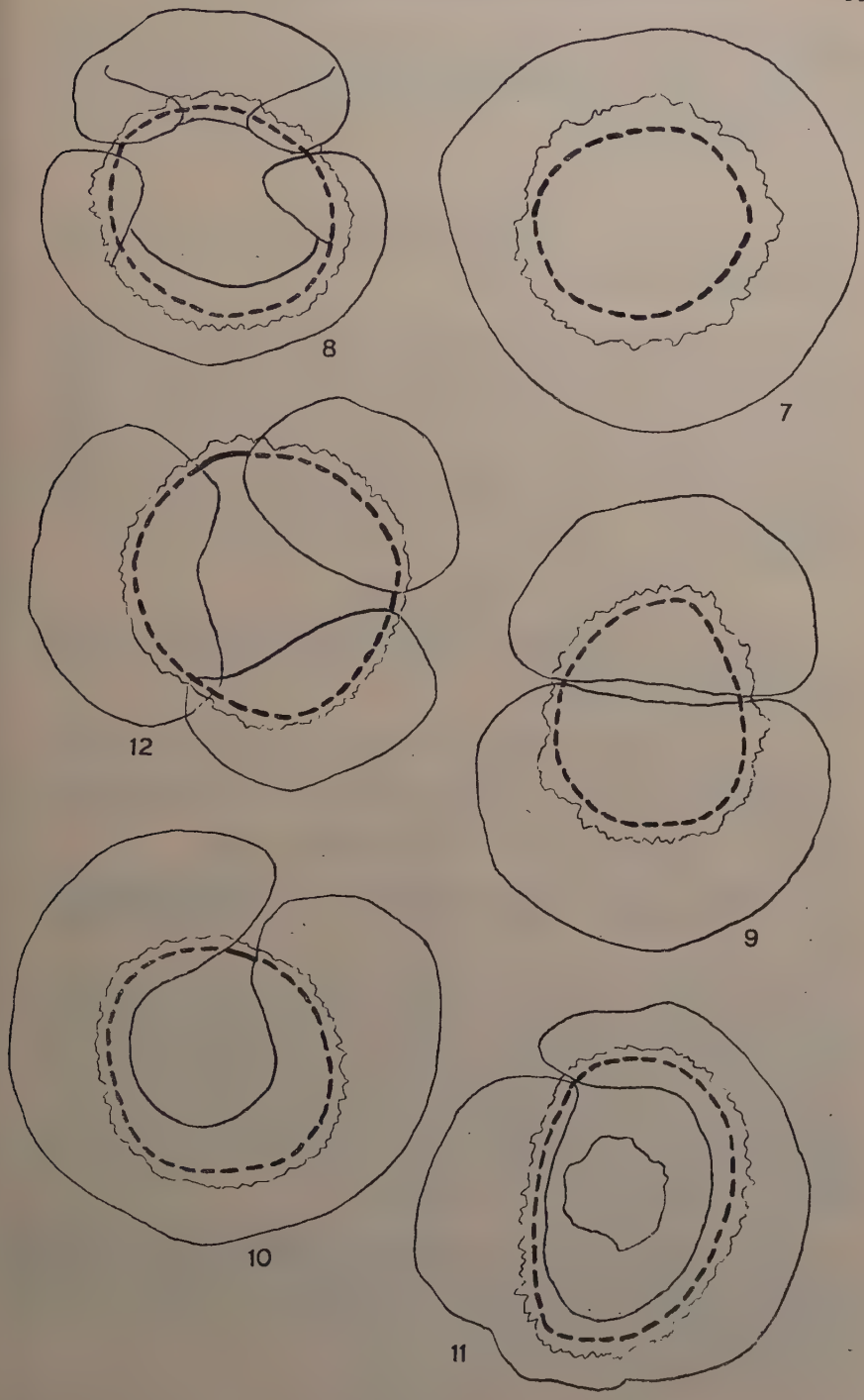
Abnormal pollen grains in the genus *Abies* are known in *A. balsamifera*, *A. nobilis* and *A.* sp. (Wodehouse, 1935, pp. 264, 266; 1935 *a*, p. 4).

(i) *Abies spectabilis* Royle (*A. Webbiana* Lindl.)

Material.—Herb., L.B.G., Darjeeling, Osmaston, 1903, Sikkim Himalayas.

Herb., L.B.G., Darjeeling, Cave 1915, Sikkim Himalayas.

Herb., B.F.S., Kurseong, Sheet No. 1412, Sikkim Himalayas.



8 FIGS. 7–12.

TEXT-FIGS. 7–12. *Pinus densiflora*. Fig. 7. A pollen grain with a single encircling wing, ×600. Fig. 8. A grain with two unequal wings each forming two projecting lobes at their free margins, ×600. Fig. 9. A grain with two unequal wings, ×600. Fig. 10. A grain with a single wing with two projecting lobes at the free margin, ×600. Fig. 11. A more or less similar grain as in Text-Fig. 10 but with a wing on the distal pole, ×600. Fig. 12. A grain with three unequal wings, ×600.

(Pl. XX, Figs. 14, 15)

The pollen grains are as described by Van Campo-Duplan (1950, p. 122) and more or less of the same size.

Normal pollen grains are about 80 μ in size and two-winged. The pollen grains from material collected by Osmaston in 1903 show a great range in size from 44·2–80 μ including wings besides several immature grains (Pl. XX, Fig. 15). The body measures 28–58 × 32–40 μ in size. A few pollen grains possess two unequal wings or 5–6 unequal wings. Pl. XX, Fig. 14 shows a grain in lateral view possessing two distal wings (one seen in photo) and four small wings attached at different levels on the proximal face. The grain measures 41·6 × 32·0 μ in size (including wings).

3. **Tsuga** Carriere

Abnormal pollen grains in the genus *Tsuga* are known in *Tsuga paltoniana* (Erdtman, 1943, Figs. 444, 445) and in the hybrids of *Tsuga* (Van Campo-Duplan, 1950).

(i) *Tsuga brunoniana* (Wall.) Carr.

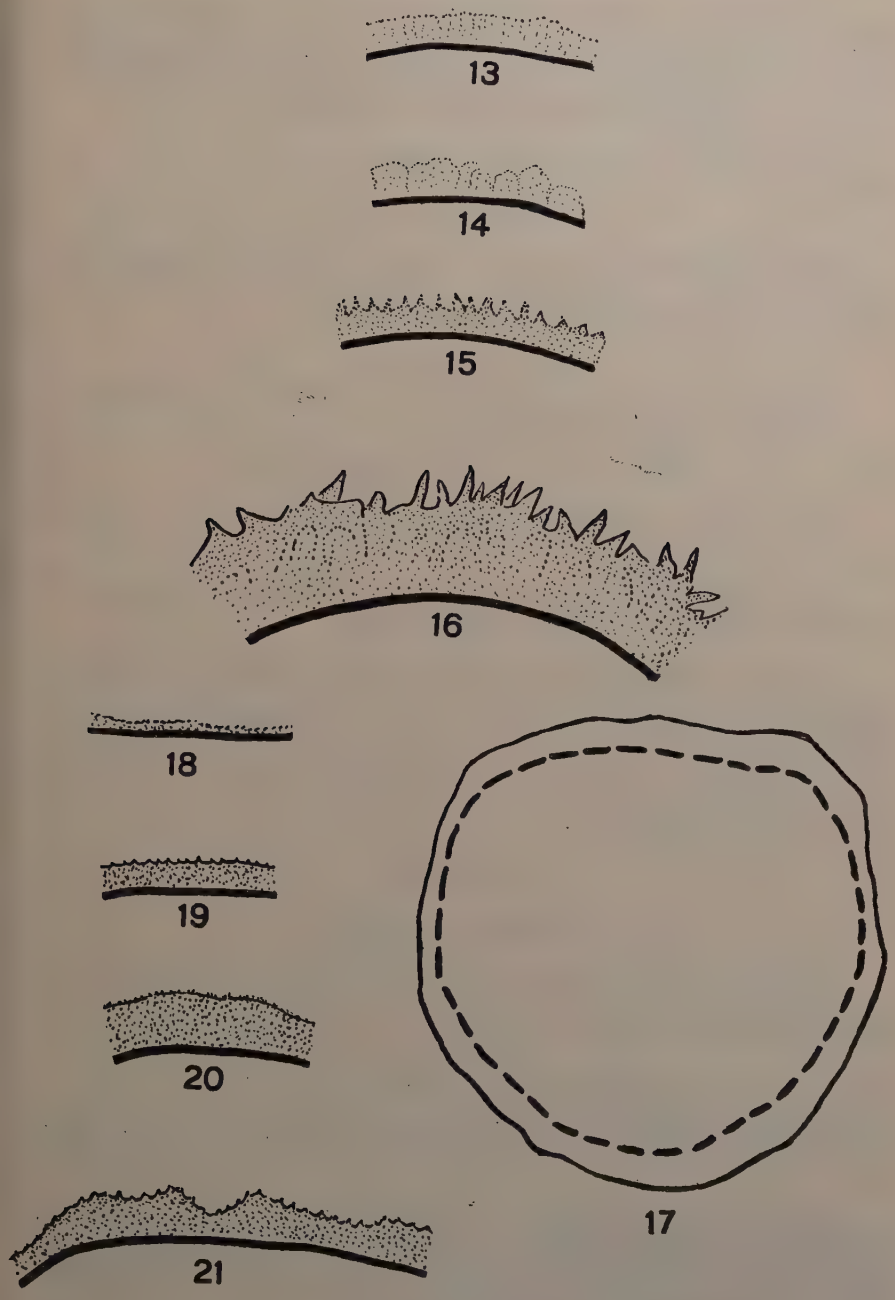
Material.—Herb., L.B.G., Darjeeling, Cave 1918, Sikkim Himalayas.

(Pl. XX, Figs. 16–18; Text-Figs. 13–16)

The pollen grains of *T. brunoniana* were first described by Van Campo-Duplan (1950, p. 139) but she did not report any abnormality.

The pollen grains in my material measure 32–41·6 × 29–38·5 μ in diameter and besides being inaperturate as described by previous workers about 30% of the grains are monocolpate with thick furrow margins (Pl. XX, Fig. 16). The grains are mostly unwinged but in some one or two rudimentary bladders are noted (Pl. XX, Figs. 17, 18). The pollen grains are mostly spinulate but a few grains are devoid of the spinules. Text-Figs. 13, 16 show exine stratifications of four grains indicating the variable thickness of the sexine and the presence and absence of the spinules in some grains.

It is interesting to note that the fossil pollen grains of *Tsuga*, *T. viridifleminipites* (Wodehouse, 1933) and *Tsuga* sp. (Kirchheimer, 1934) known from the Tertiary horizon had rudimentary bladders and a germinal furrow.



FIGS. 13–21.

TEXT-FIGS. 13–21. *Tsuga brunoniana*. Figs. 13–16. Parts of exine stratification of four grains showing the variable thickness of the sexine. In the grains from which Text-Figs. 18 and 19 are drawn the spinules are not present, ×1,200. Figs. 17–21. *Araucaria Bidwillii*. Fig. 17. A grain with a wing-like sexinous projection encircling the body, ×600. Figs. 18–21. Parts of exine stratification from four grains showing the variable thickness of the sexine, ×1,200.

ARAUCARIACEÆ

Araucaria Juss.

Abnormal pollen grains in the genus *Araucaria* are not known so far to the best of my knowledge. The observations given below are, therefore, being reported for the first time.

(i) *Araucaria Bidwillii* Hook.

Material.—Bot. Gardens, Bangalore, G. Erdtman, R. N. Lakhanpal and V-Mittre, 1956.

(Pl. XX, Figs. 19–20; Text-Figs. 17–21)

The normal pollen grains, 32–38·5×35–37 μ in diam., are inaperturate, spinulate.

It is interesting to find a few pollen grains which are monocolpate and trichotomocolpate (Pl. XX, Figs. 19, 20).

The exine is distinctly 2-layered, the sexine is comparatively thicker than the nexine. In some grains the sexinous layer is several times thicker than the nexine and varies in thickness from grain to grain. Text-Fig. 17 shows a grain surrounded alround by a broad wing-like sexine. Text-Figs. 18–21 show the exine stratifications of some grains with variable thickness of the sexine. The sexinous layer is either wavy or of unequal thickness.

PODOCARPACEÆ

Podocarpus L. Heritier.

Abnormal pollen grains in the genus *Podocarpus* are known in *P. macrophyllus* D. Don and *P. nivalis* Hook. (Wodehouse, 1935, p. 277) Van Campo Duplan, 1950, p. 157–58; Cranwell, 1940, p. 33).

(1) *Podocarpus macrophyllus* D. Don.

Material.—Herb., L.B.G., Darjeeling, Bahadur, 1952, Darjeeling.

(Text-Fig. 22)

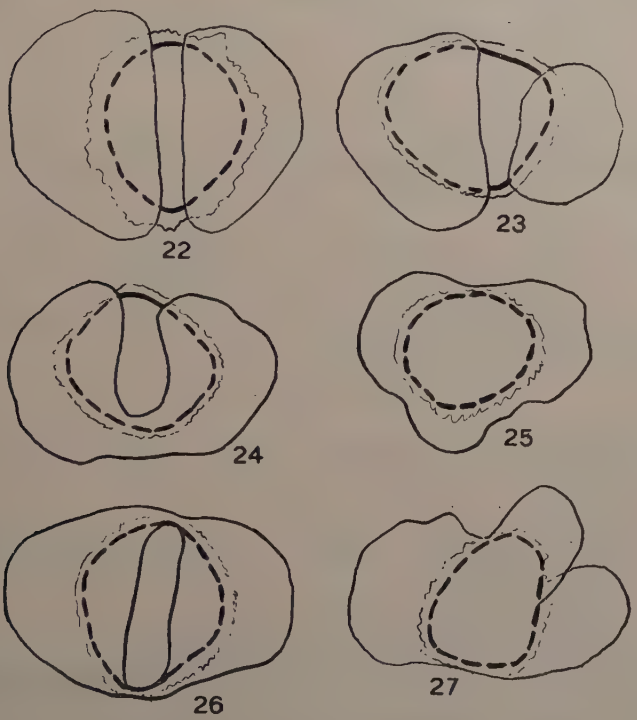
The material shows more or less similar kind of abnormality as reported by Wodehouse (*loc. cit.*). A few pollen grains possess unequal wings (Text-Fig. 22). Normal pollen grains in my material range in size from 28–45 μ (including wings) and differ remarkably from those described by Wodehouse (*loc. cit.*).

(2) *P. neriifolius* D. Don.

Material.—Herb., L.B.G., Darjeeling, Bahadur, 1950, Darjeeling.

(Pl. KX, Fig. 21; Text-Figs. 23–27)

The normal pollen grains are as described by Wodehouse (1935, p. 278). The pollen grains measure 22·5–23·6 μ in size (including wings), the body is about 14·5 × 12·8 μ.



FIGS. 22–27.

TEXT-FIGS. 22–27. Fig. 22. *Podocarpus macrophyllus.* A grain with two unequal wings, ×600. Figs. 23–27. *Podocarpus neriifolius.* Fig. 23. A grain with unequal wings, ×600. Fig. 24. A grain with two wings, fused at one of the sides, ×600. Figs. 25,27. A grain with a single wing encircling the body showing three lobes. Fig. 26. A grain with a single wing with two lobes, ×600.

The abnormal pollen grains are either 2-winged bearing two unequal air-sacs (Text-Fig. 23) or bearing two fused wings at the ventral surface (Text-Fig. 24). Text-Figs. 25 and 27 show a grain with a single bladder differentiated into three lobes. The grain in Pl. XX, Fig. 21; Text-Fig. 26 is a one-winged grain with two lobes.

GNETACEÆ

Gnetum L.

Except the size variation in *G. leptostachyum* and *G. neglectum* (Wodehouse, 1935, p. 294) no other abnormalities are known so far in the pollen grains of *Gnetum*.

(i) *G. scandens* Brandis.

Material.—Herb., L.B.G., Darjeeling, Cave 1910, Sikkim Himalayas.

Herb., L.B.G., Darjeeling, Cave 1913, Sikkim Himalays.

(Pl. XX, Fig. 22)

The normal pollen grains are $8–10 \times 6 \cdot 5–8\,\mu$ in size, ovoid in shape, inaperturate and spinulate. The pollen grains in the material collected in 1910 were found to be slightly larger in size than those from material of 1913.

About 40–50% of the pollen grains in the material of 1913 possess some pore-like apertures which range in number from 1–7 (Pl. XX, Fig. 22). Each pore-like aperture measure $1 \times 1 \cdot 6\,\mu$ and is more or less circular with distinct margins. In some grains the pore membranes are also flecked with spinules.

Discussion

Various kinds of abnormalities known in the pollen grains of gymnosperms are:—

1. Variations in size.
2. Variable number of wings on the winged grains—typical and atypical forms.
3. Variations in exine pattern.
4. Presence of wings on the unwinged grains.
5. Presence of aperture(s) on the non-aperaturate grains.

Abnormalities of the types 3–5 are of rare occurrence and consequently very little is known about such abnormalities. Variation in size is very common and is certainly known to be due to a change in the chromosomal set-up or other environmental or physiological factors. Variations in the number of wings in the winged pollen grains have attracted much attention and several workers have contributed to the significance of this kind of abnormality and consequently some phylogenetic and evolutionary importance has more than often been attached to such aberrant forms of the winged pollen grains as the 1-winged, 3-and 4-winged ones. The theory of recapitulation and the conception of the system of anemochoriqie (the successive reduction of the one wing into 2, 3 and 4 wings) have been postulated by Florin (1936), Van Campo-Duplan (1950) and recently supported by Lakhanpal and Nair (1956).

Abnormalities are believed to be caused whenever the normal equilibrium in the life of an organism is upset (Sahni, 1925). It may be due to a change in the chromosomal number or due to environment or physiological factors.

Experiments on the pollen grains of both angiosperms and gymnosperms reveal that the size is influenced by environmental (Jones and Newell, 1948), genetic and chromosal factors (Sampath and Ramnathan, 1951; Mehra, 1947). Venkatasubban (1950) believes that the heteromorphism in *Drosera indica* is probably due to nutrition. The occurrence of occasional giant grains in *Mangifera* is explained by Mukherji (1951) to be due to the failure of second division after meiosis in the pollen mother cell which results in a restitution nucleus leading to the duplication of chromosomes in the male gamete. When this male gamete meets a normal or ordinary female gamete, gigantism results.

A study of the pollen grains of hybrids shows that the abnormalities may also be due to hybridization. The occurrence of various number of the wings on 2-winged pollen grains and wings on unwinged pollen grains has been very well illustrated by Van Campo-Duplan (1950) from a study of several conifer hybrids.

Variations in exine pattern and occasionally size and apertures may also be attributed to their full, partial or incomplete development. In pollen preparations of recent material very often the buds of all sizes may be mixed and the slides prepared sometimes resulting in such variations as noted above. Soon after the release from the tetrad stage the pollen grain begins to differentiate the two layers of the exine, the apertures and the exine pattern till it gains maturity. The pollen grains of *Pterospermum heyneaum* described by Venkata Rao (1949, p. 185, Fig. 1 *g* and *h*) may be taken for instance. In this species the pollen grains soon after their liberation are of lenticular form with a thin exine but later become spherical. Gradually the exine with its germ pores and outgrowths is secreted. Another example may be taken of the pollen of *Ephedra foliata* where the number of ridges has been found to be variable by various workers, *viz.*, 16 ridges are described by Maheshwari (1935), 15 by Wodehouse (1935), 15–18 by Mulay and Khubchandani (1944) and 10–12 but occasionally 19 by Mulay and Nair (1952). The maximum number of ridges in *E. foliata* found by these workers is 19 and minimum 10 but 15–16 probably represents the average normal number. Very likely the materials investigated by these workers were not at the same stage of maturity.

Significance of the abnormalities.—The significance of some of the megascopic abnormalities of the gymnosperms has been pointed out by some workers, *viz.*, Doyle and Oleary (1934), Florin (1951), Eames (1952), Mehra (1951), Wilde and Eames (1955), etc., who have shown that the abnormal fructifications of Ginkgoales, Gnetales and also of Coniferales have some palæobotanical significance. But Eames (*loc. cit.*) and Zimmerman (1948) look upon some abnormalities as monstrosities. Taking some examples of the pollen grains we find that

the abnormal 1-winged pollen grains might be looked upon as having a palæobotanical significance as believed by Florin (1936) and a due regard may also be paid to the abnormal 3-winged forms but there is no evidence to support the palæobotanical significance of such atypical and irregular forms as described in this paper and by the previous workers. Four-winged pollen grains occur only as abnormal and according to the successive reduction theory of the formation of more than two wings from one wing, most of the conifers of today should have produced only 4-winged pollen grains if any evolutionary significance can be attached to such an abnormality but the evidence is quite contary to the theory. Then the 4-winged pollen grains have no palæobotanical significance whatsoever; they have occurred equally as abnormal forms in the Jurassic conifers (Vishnu-Mittre, 1956) and no record is known so far of fossil and living conifers which had normal grains with the 4-wings.

The atypical forms of the pollen grains such as possessing wings at different levels of the body or bearing additional wings on either or both of the poles or showing fusion of the wings in various ways, etc., do not either suggest that they are the intermediate forms between grains of the remote ancestors and those of their modern derivatives. They are in fact the malformed grains and should, therefore, be looked upon as monstrosities. They should also not be considered to represent the successive stages through which 1-winged pollen grain could be conceived to have evolved into the 2, 3 and 4-winged pollen grains or grains with more than 4 wings.

Tertiary pollen grains of *Tsuga*, *T. viridifluminipitis* and *T.* sp. (Wodehouse, 1933; Kirchheimer, 1934) are known to possess both these characters. Though it is difficult to know whether the Tertiary fossils produced normal or abnormal pollen grains yet some palæobotanical significance can be attached to the abnormal *Tsuga* pollen described above.

The abnormal pollen grains of *Gnetum scandens* are further interesting in possessing pore-like apertures which according to our present knowledge of fossil and of living grains are the characters of the angiospermous pollen grains. Thus the abnormality of this kind as in *Gnetum* does not seem to indicate any palæobotanical significance. It rather points towards a character which appears very late in the evolution of plant kingdom. Does this kind of abnormality signify progressive evolution?

The presence of apertures and the wing-like broad sexinous development in the pollen grains of *Araucaria Bidwillii* described above may be interpreted to have palæobotanical significance since the araucarias are also believed to belong to the line of evolution headed by the Cordaitales and the lebachias (Florin, 1951, p. 360; Wilde and Eames, 1955) which produced winged and aperturate pollen grains. It is interesting to note that the apertures in these ancient gymnosperms were either of the triradiate type or of single furrow type.

Thus there are certain abnormalities which can be looked upon as possessing palæobotanical significance (atavastic, Arber, 1919), others may be believed to show the future course of evolution a species is likely to adopt and several others may be classed as monstrosities or the malformations.

The significance of abnormalities may best be explained with the help of Arber's Law of Loss or by the Law of Irreversibility (Arber, 1918, 1919). The 1-winged nature of the pollen grains are the characters which are lost in geological times and are normally not produced now. In the chromosomal aberrations, polyploidy or hybridization the plant species today find occasion to replace the lost character (fall back) which cannot be reproduced but is constructed afresh in some different mode. In doing so the malformations—the atypical forms also result which have no significance whatsoever.

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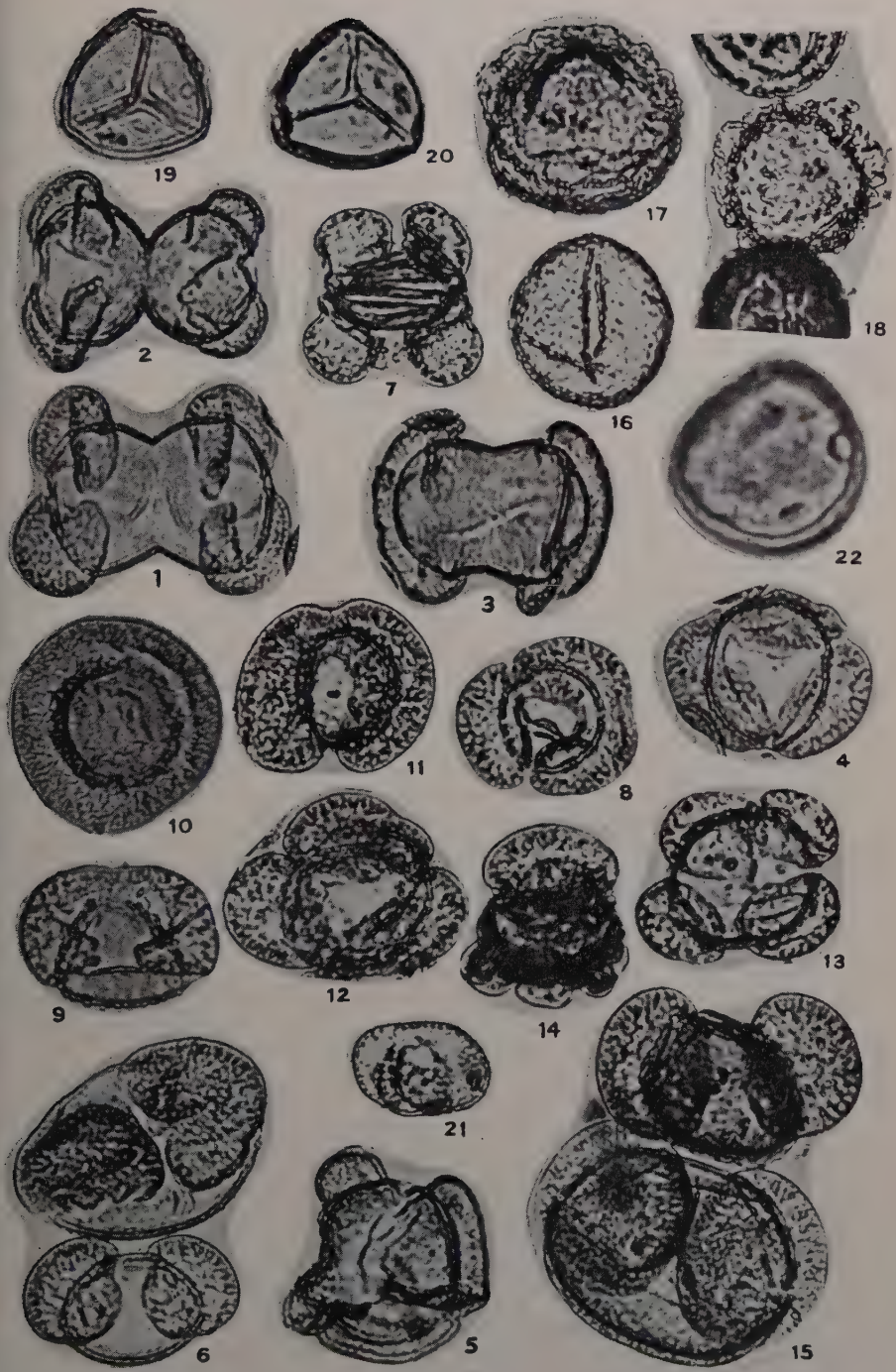
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Explanation of Plate XX

(All Figures, × 290 and from untouched negatives)

Pinus insularis

Figs. 1–3. Giant diads fused by their proximal faces. The diad in Fig. 3 shows that the grain on the right has a single bladder.

Fig. 4. A grain with two unequal wings, the larger wing is two-lobed, the pollen grain appearing three-winged.

Fig. 5. A grain with four unequal wings. Two of the wings attached on one of the poles while the other two probably attached on the opposite pole.

Fig. 6. Showing a normal (smaller) two-winged pollen and a giant (larger) two-winged pollen grains.

Pinus roxburghii

Fig. 7. A diad.

Fig. 8. A one-winged grain with three lobes.

Pinus densiflora

Fig. 9. A pollen grain showing a single encircling wing with two free-lobes on one of the sides.

Fig. 10. A pollen grain with a single wing.

Fig. 11. A pollen grain with a single wing with two notches.

Fig. 12. A four-winged pollen grain with three-wings in one plane and the fourth in the other.

Fig. 13. A four-winged pollen grain.

Abies spectabilis

Fig. 14. A pollen grain seen from a lateral view showing two wings (one seen in photo) attached on the distal face while five small wing-like projections borne on the proximal face of the body.

Fig. 15. Two pollen grains showing the size extremes.

Tsuga brunoniana

Fig. 16. A pollen grain with a single furrow.

Fig. 17. A pollen grain with a rudimentary bladder (lateral view).

Fig. 18. A pollen grain with two rudimentary bladders.

Araucaria Bidwillii

Figs. 19–20. A pollen grain at two different focii showing a three-slit (trichotomocolpate) aperture.

Podocarpus neriifolius

Fig. 21. A pollen grain with a single encircling bladder.

Gnetum scandens

Fig. 22. A pollen grain with four pore-like apertures.

GENUS *RICCIA* IN INDIA

I. A Reinvestigation of the Taxonomic Status of the Indian Species of *Riccia**

By S. K. Pandé and Ram Udar

(*Department of Botany, Lucknow University, Lucknow*)

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Introduction

In his comprehensive treatment of the genus *Riccia*, Stephani (1900; 1917–24) included the following five species from India including one from Ceylon:

1. *R. discolor* L. *et* L., based on sterile specimens collected by Wallich (Nepal) and Duthie (Dehra Dun),
2. *R. crispatula* Mitt., collected by Gardner (Matale, Ceylon),
3. *R. bulbifera* St., collected by Kurz (Bengal),
4. *R. microspora* St., collected by Kurz (Bengal) and
5. *R. gollani* Levier, from a collection made by Gollan (Himalayas).

Of the five species enumerated above, *R. discolor* grows luxuriantly in nearly all parts of the country and a brief discussion of this species has already been given by Udar (1957 *a*). A careful search in the specimens of *Riccia*, collected by Pandé during the last 30 years, did not reveal the presence of any of the other four species although extensive collections are represented from the territories from which these species have been originally described. Also, in his treatment of the genus *Riccia*, Stephani (1900) lays great emphasis on the vegetative characters which are extremely variable and, therefore, diagnostically unreliable. This is particularly so because Stephani's study is based on specimens obtained from diverse geographical and ecological habitats which thus inherently carried the vegetative traits typical of their home localities. The chances of confusion, with such a reliance on vegetative features, naturally acquires enormous proportions. Repeated failures in collecting some of the species described by Stephani from India (1900; 1917–24) led to a doubt about their validity. It was, therefore, thought desirable to critically re-examine the Indian species of *Riccia* from Stephani's herbarium with a view not only to asses their authenticity but also to make fresh attempts to collect those which have not been described since their first report.

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Unfortunately the species of *Riccia* from India have not so far been adequately and completely described. This difficulty was obviously realized by Jones (1957), while describing the Ricciaceæ from Tropical Africa, when he remarked that the " group is also well represented in other warm countries such as India, but published descriptions are usually much too inadequate, especially as regards spores, to make it possible to say whether any of the African species are identical with those of other tropical countries ".

The only compact illustrated taxonomic treatment of the genus in India is by Kashyap (1929) but unfortunately some of his species are not authentic and several of the others inadequately described and incompletely illustrated. A need for a thorough illustrated description has long been felt and an attempt is now being made to present a complete picture of the genus represented in India.

Material and Method

Herbarium specimens for this communication were obtained, from Stephani's Herbarium, through the courtesy of Dr. C. E. B. Bonner, Conservatoire Botanique, Genève. The following specimens were examined†:

Riccia discolor L. *et* L.

1. No. 39,
   Hab. Nepal,
   Portion de l'original.

2. No. hb. Levier 338,
   Hab. N. W. Himalayas,
   Dehra Dun, Mussoorie,
   6–7000′,

   Date: 6th August 1881,
   Leg. J. F. Duthie,
   ex hb. E. Levier,
   Portion de l'échantillon des collections Stephani.

Riccia bulbifera Steph.

1. No. 1806 (hb. Berol. 937),
   Hab. Calcutta, communis in horto Botan,
   Leg. Kurz.,
   ex Herb. Berol.,
   Portion de l'échantillon des Collections Stephani.

2. No. 53
   Hab. India Orient. Bengal. Raj Mahal Hills prope Sahibganj,

   ex Herb. Berol.,
   Portion du type. Date: 19–9–1868.

† Details as given on the packets.

Riccia crispatula Mitt.

No. 147,
Hab. Ceylon: Matale,
Leg. Gardner,
ex Herb. Kew,
Portion de l'original.

Riccia microspora Steph.

1. *Hab.* Upper Assam,
Leg. Griffith,
ex Herb. Kew,
Portion de l'échantillon des collections Stephani.

2. *Hab.* Tonkin: Cercle du Laokay,
Leg. Montier,
ex Herb. du géenéral E. G. Paris,
Portion de l'échantillon des collections Stephani.

Riccia gollani Levier.

No. hb. Levier. 3973,

Hab. N.-W. India. Sahemanpur, on old brick tombs in Mahomedan burial ground near Government Bot. Gardens, 990 ft.

Date: 7th January 1901,
Leg. W. Gollan,
ex hb. E. Levier,
Portion de l'original.

In many cases the specimens were scanty but nearly all of them were fertile and could thus be thoroughly studied. Stephani's unpublished drawings of these species were also available (from a set of a large number of his drawings) for study through the kindness of Dr. Herman Persson.

Authentic specimens of *R. billardieri* Mont. *et* N. from Herbarium Bogoriense, obtained through the courtesy of Dr. W. Meijer, was utilized for comparing specimens of *R. bulbifera* St.

All the herbarium specimens were studied after soaking them in warm water for 12–24 hours to ensure maximum stretching of tissues.

In several species the mature spores are black and opaque at maturity or of such a dark shade as to obscure the sculpturing on the spores which furnish a highly reliable taxonomic character. Treatment of such spores with dilute nitric acid for about half an hour brought about the reticulations clearly. Excellent results were also obtained by treating the spores with Chloral hydrate as recommended by Warnstorf (*see* Macvicar, 1926).

A large number of specimens from the extensive 'PANDÉ COLLECTIONS' were utilized for detailed descriptions of the various species.

OBSERVATIONS

Our study of the Indian species of *Riccia* from Stephani's Herbarium has yielded the following results:

1. *R. gollani* Levier is a synonym of *R. discolor* L. *et* L.
2. *R. bulbifera* St. is a synonym of *R. billardieri* Mont. *et* N.
3. *R. crispatula* Mitt. is a genuine species and has yet to be collected from India being only known from Ceylon so far.
4. *R. microspora* St. is a synonym of *R. frostii* Aust.

A discussion for the above view is presented below:

DESCRIPTION

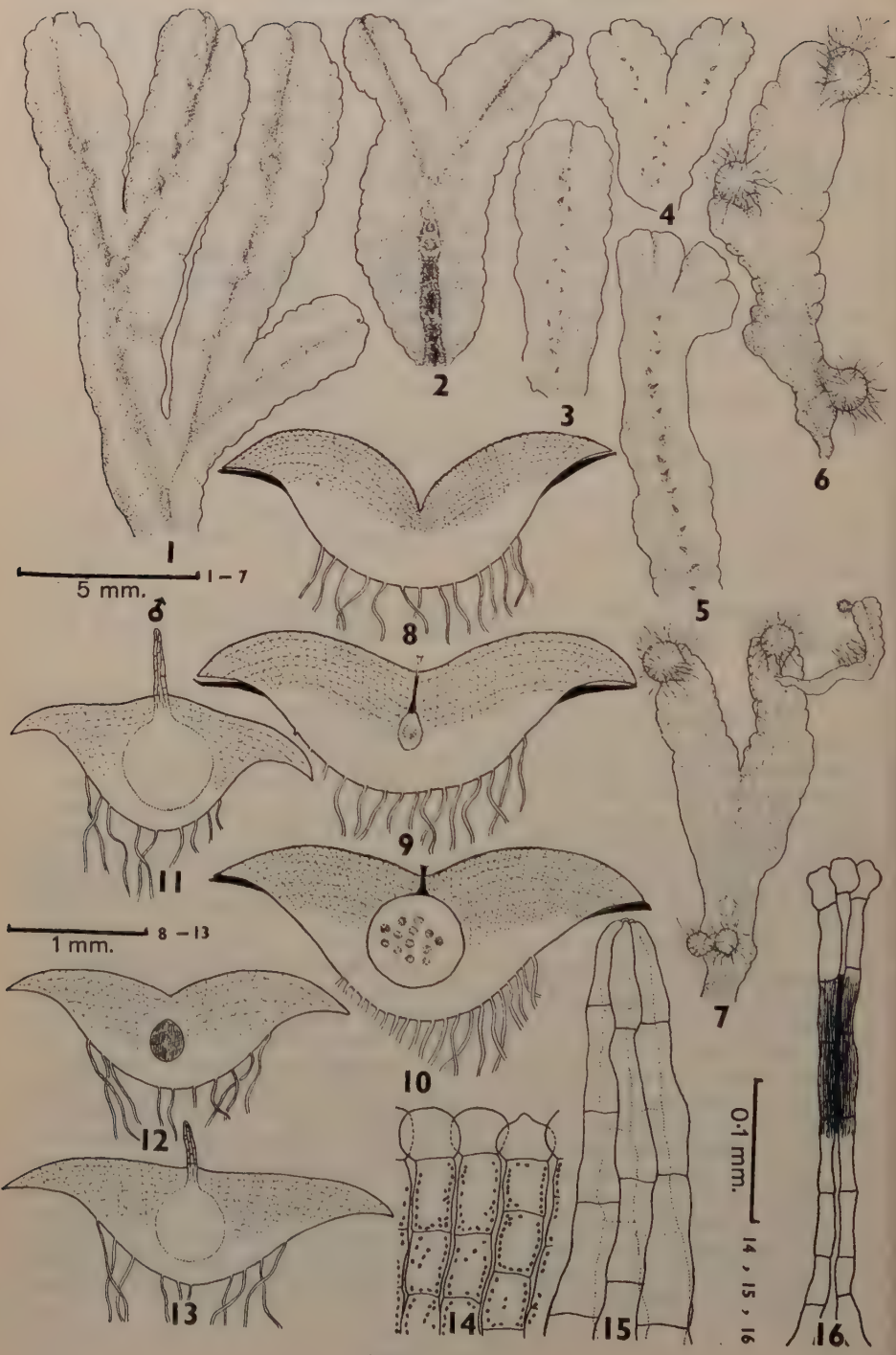
Riccia discolor L. *et* L. Pugill., IV.

Syn. *R. himalayensis* St. (MS). in Kashyap, J. *Bombay nat. Hist. Soc.*, 1916, **24,** 349.

R. gollani Levier, in Stephani's Sp. Hep., 1917–24, **6,** 2. (Text-Figs. 1–16; 45, 46; Pl. XXI, Fig. 1; also Udar, 1957*a*, Figs. 1–4; 10, 11).

R. discolor, one of the earliest known species of the genus *Riccia*, was established by Lindenberg and Lehmann (1832) for a sterile specimen collected by Wallich from Nepal. This species was subsequently listed by Mitten (1861) and also by Stephani (1900). The latter has given some details of the vegetative characters of the thalli also referring to this liverwort collected by Duthie in 1881 from Dehra Dun which is one of the many valuable specimens of the famous Herbarium of E. Levier at present under investigation in this laboratory. Later this species was listed by Kashyap (1914) on the basis of a specimen collected by him from Mussoorie. The same was subsequently referred by Stephani to a new species, *R. himalayensis* (see Kashyap, 1915, p. 18) and the plants were then described by Kashyap under this name as a *diœcious* species but later Kashyap (1932) referred this species as *diœcious as well as monœcious* and *amended the earlier spore description.* From this confused description arose great errors in interpreting *R. discolor* subsequently. A discussion on this aspect has been given earlier by Udar (1957 *a*) where it has been shown that *R. himalayensis* has no specific status. In fact it is a composite species embracing *R. discolor*, *R. billardieri* and *R. gangetica.*

From an examination of *R. gollani* from Stephani's Herbarium, it has become evident that this species is also a synonym of *R. discolor*. *R. gollani* is based on specimens collected by Gollan from Himalayas and has been described by Stephani (1917–24) as a sterile species from



FIGS. 1–16

TEXT-FIGS. 1–16. *Riccia discolor* L. *et* L. Fig. 1. Robust female thalli. Fig. 2. Female thallus showing dehiscence of capsule. Figs. 3–5. Male thalli. Figs. 6, 7. Thalli showing tubers. Figs. 8–10. Cross-sections of a female thallus from the apex, in the middle and at the base respectively. Figs. 11–13. Cross-sections of a male thallus from the apex, in the middle and at the base respectively. Fig. 14. A portion of cross-section of thallus showing assimilatory filaments and the epidermal cells. Fig. 15. Antheridial papilla magnified. Fig. 16. Neck of an archegonium.

a study of the original specimens. Our examination of these very specimens clearly demonstrated the presence of sporophytes (Pl. XXI, Fig. 1) with numerous spores and it is unfortunate how they could have escaped observation.

R. gollani (see Stephani, 1917–24) is characterized by large thalli (about 12 mm. long and 4 mm. broad) which are simple and anteriorly sulcate. The epidermal cells are prominently papillose and the scales are purple and large extending beyond the margin. These vegetative features, as well as Stephani's unpublished drawings of this species, strongly answer to *R. discolor* and the structure of the spores (Text-Figs. 45, 46; also Udar, 1957 *a*, Figs. 10, 11) unquestionably settles the similarity of the two species.

Since no authentic complete account of *R. discolor* has so far been published, the description given below will serve to fill the gap in the clear elucidation of the species.

Diœcious, light green, *thalli* 1–3 times dichotomously branched, overlapping or forming well-developed rosettes, compact with narrow air spaces; *epidermal cells* hyaline, oval-papillate; ventral surface with numerous simple and tuberculate rhizoids, *scales* semi-lunar, overlapping, usually deep pink, projecting beyond the thallus margin; *cross-section* of the thallus usually 3–4 times broader than high; *male plants* 3–6 mm. long and 2–3 mm. broad, anteriorly sulcate but flat or nearly convex behind, antheridia in 1–3 rows with conspicuous hyaline or pink antheridial papillæ projecting 200 μ–350 μ above the thallus surface; *female plants* larger and dorsally sulcate throughout, 4 mm.–12 mm. long and 2–4 mm. broad, archegonia in the median grove, archegonial neck up to 100 μ, after fertilization the middle part turning violet and the rest remaining more or less colourless; *capsules* in 1–2 rows coming out by the rupture of the dorsal thallus surface forming a deep wide channel, *spore* dark-brown at maturity, outer face 80–120 μ in diameter, regularly reticulate with low walls separating the reticulations, 5–10 in the diameter, tri-radiate mark inconspicuous, wing absent.

R. discolor is one of the commonest and the most widely distributed monsoon species. With the first shower of rains, near about middle or end of June, the plants start to grow and during September-October reach full maturity showing mature sporogonia although under favourable conditions they continue to grow well upto December–January.

At the end of the growing season the plants develop conspicuous perennating tubers (Text-Figs. 6, 7) by which they tide over the

unfavourable drought conditions and resume growth at the advent of favourable weather.

R. discolor belongs to the section Euriccia (non-ciliate) and is the only diœcious species known so far belonging to this section from India. It can easily be recognized by the numerous prominently projecting antheridial papillæ of the male plants. These develop conspicuous anthocyanin in plants growing in exposed places. The female thalli are larger and the dorsal sulcus is continuous throughout the entire length of the thallus.

The plants often grow closely intermingled with *R. billardieri* and *R. gangetica* (see Udar, 1957 *a*, Fig. 1). Both of these are, however, monœcious and could thus be easily separated. Besides, these present certain other pronounced and characteristic differences. The thalli of *R. gangetica* are bluish-green and usually much smaller in size and the spores normally larger in size with greater number of reticulations (about 11–16) which are of smaller size. The thalli of *R. billardieri* have relatively broader segments (usually 4–5 times as broad as high) and the spores show prominent projections.

Riccia billardieri Mont. *et* N., *Syn. Hep.*, 602.

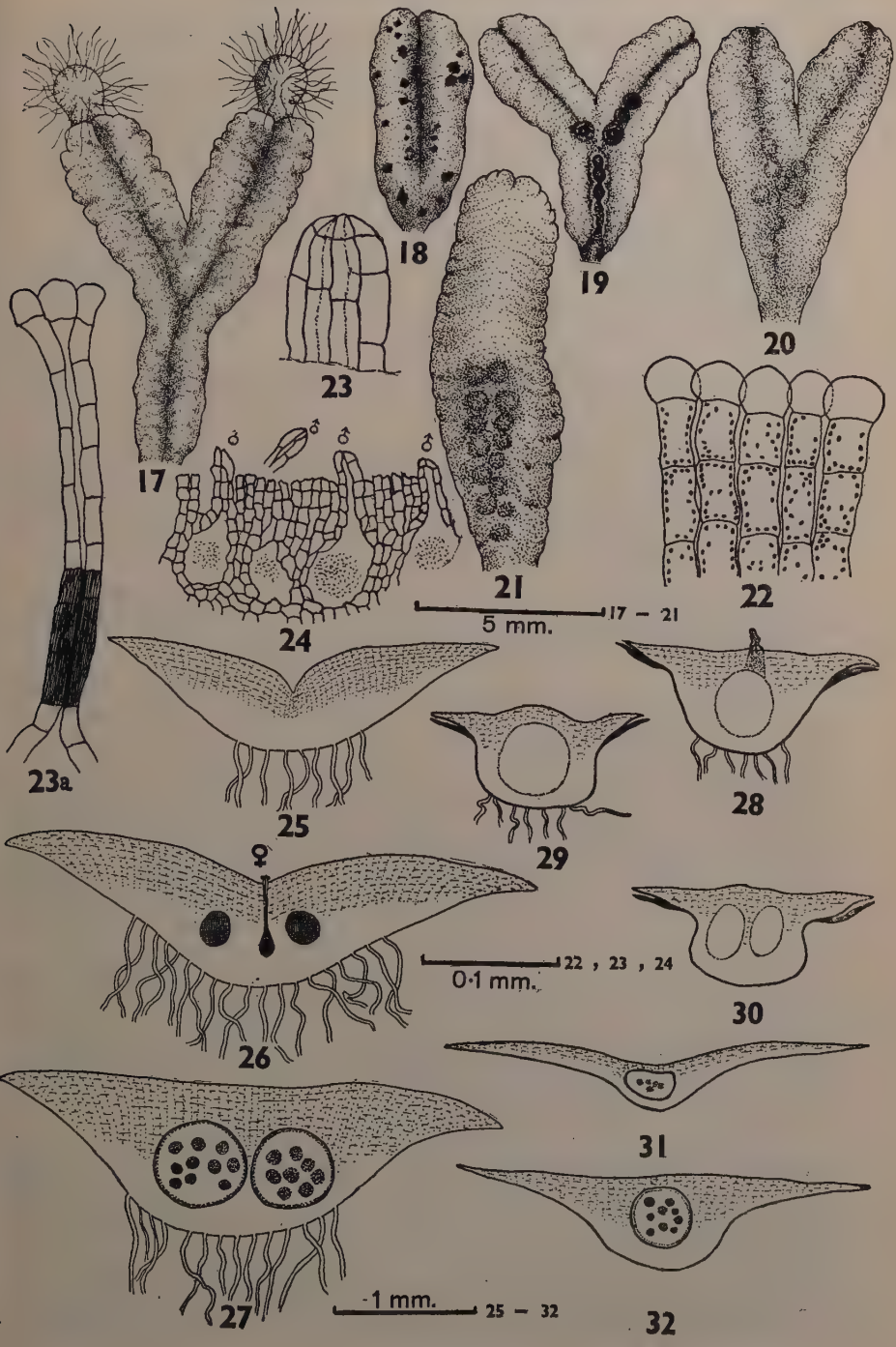
Syn: *R. bulbifera* St. *Sp., Hep.* 1900, **1**: 24–25.

(Text-Figs. 17–27; 47, 48; Pl. XXI, Fig. 6; also Udar, 1957 *a*, Figs. 1, 6–8).

From India *R. billardieri* was first reported by Schiffner (1900) from Elephanta, Bombay, and since then apparently escaped attention of subsequent workers. It has now been shown to be the monœcious species included by Kashyap (1929; 1932) in the *R. himalayensis*—complex (see Udar, 1957 *a*). It is also one of our widely distributed species and is almost as common as *R. discolor*.

R. billardieri has also been known to the Indian hepaticologists as *R. bulbifera* St. from the late 19th century up to the present day. The latter species, instituted by Stephani (1900), is based on specimens collected by Kurz from Raj Mahal Hills near Sahibganj, Bengal, in 1868. According to Stephani (1900) the species is monœcious (?) and characterized by large thalli (up to 25 mm. long) which are several times furcate, ligulate and anteriorly deeply sulcate and the rest plane. In cross-section they are more or less three times broader than high. The mid-rib is abruptly drawn out in wings and the scales are large and purple hardly extending beyond the margin. The spores are large, 102 μ, reticulate-lamellate, only 5 areoles in the diameter with the angles of the lamellæ upturned and subdentate. At the apex the thalli show solitary pyriform tubers (Pl. XXI, Fig. 6).

A comparison of the type specimens of *R. bulbifera* with authentic *R. billardieri* from Herbarium Bogoriense leaves absolutely no doubt about the two being the same. In the vegetative features of the two species the only significant difference seems to be the presence of tubers


17
18
19
20
21
22
23
23a
24
25
26
27
28
29
30
31
32
♂
♀
5 mm.
17 – 21
0·1 mm.
22 , 23 , 24
1 mm.
25 – 32

FIGS. 17–32.

TEXT-FIGS. 17–32. *Riccia billardieri* Mont. *et* N. Fig. 17. A thallus showing apical tubers. Fig. 18. Dorsal view of a thallus showing black fungal perithecia. Fig 19. Thallus showing the dehiscence of sporophyte. Figs. 20, 21. Thalli showng distribution of sex organs and sporophytes. Fig. 22. A portion of a cross-section of thallus showing assimilatory filaments and epidermal cells. Fig. 23. Antheridial papilla. Fig. 23 *a*. Archegonial neck. Fig. 24. L.s. of a thallus through 4 antheridia (♂). Figs. 25–27. Cross-sections of a thallus at the apex, in the middle and at the base respectively. *Riccia cripsatula* Mitt. Figs. 28–30. Cross-sections of a male thallus at the apex, in the middle and at the base respectively. Figs. 31, 32. Cross-section of a female thallus behind the apex and at base respectively.

in *R. bulbifera* (Pl. XXI, Fig. 6) which, however, are mere ecological adaptations and do not have valid specific significance. Besides, tubers have recently been observed in *R. billardieri* as well (Udar, 1957 *b*, Fig. 1).

Stephani's account of the spores of *R. bulbifera* appears to be wrong. The size of the spore is larger (being up to 150 μ and not only 102 μ as given by Stephani) and the number of reticulations also more (being up to seven and not *only* five as given by Stephani). However, the size and the number of the reticulations given by Stephani are well within the limits of *R. billardieri* and the two are structurally absolutely identical. *R. bulbifera* thus does not deserve a specific rank and has been reduced to a synonym of *R. billardieri.*

Since *R. billardieri* has been widely confused in the past and no authentic detailed account is available in literature on Indian Bryology an illustrated taxonomic account is presented below.

Monœcious dark-green, once, rarely twice dichotomously branched, *thalli* overlapping or usually in incomplete rosettes, often forming perfect rosettes, 3–15 mm. long and 2–3 mm. broad, anteriorly sulcate but nearly flat behind; *epidermal cells* hyaline, oval-spherical; ventral surface with simple and tuberculate rhizoids, *scales* prominent, purple at maturity, entire, semi-lunar, scarcely projecting beyond the thallus margins, *cross-section* of the mature thallus usually 4–5 times as broad as high, often much broader; antheridia in 1–3 rows; archegonial necks projecting above the thallus surface mixed with the antheridial papillæ, the neck of the archegonium after fertilization turning violet at the base and the rest remaining colourless; *capsules* often in 1–3 rows, exposed by rupture of overlying tissues; *spores* reddish-brown or dark-brown, 80–150 μ along the outer face, regularly reticulate with 5–7 reticulations across, corners of the walls of reticulations conspicuously high and expanded or truncate projecting out prominently on the surface, a thin undulating delicate membrane covers these projections, tri-radiate mark inconspicuous.

There seems to be a great variability in the size of spores in this species. In specimens from Mangalore (7540) spores average 80–99 μ, in Calcutta specimens (7035) from 112–125 μ, in local specimens (7010) from 112–130 μ and in a specimen from South India (7544) from 132–150 μ.

At the end of the growing season, under certain conditions, as in *R. discolor*, the plants develop conspicuous apical tubers (Text-Fig. 17).

Occasionally some thalli show externally conspicuous black perithecia (Text-Fig. 18) of an ascomycetous fungus which are embedded in the thallus tissue. The hyphæ are branched, septate and intra- and inter-cellular.

Riccia gangetica Ahmad in *Curr. Sci.*, **11**: 433–434, 1942.

(Text-Figs. 33–44; also Udar, 1957 *a*, Figs. 1, 5, 9)

R. gangetica was instituted and described by Ahmad (1942) from specimens growing locally and at Aligarh. The salient taxonomic features stressing the identity of this species has already been given by Udar (1957 *a*). A subsequent cytological investigation (Udar and Chopra, 1957) has shown it to be one of our most interesting species in being hexaploid with $2n = 48$. Our knowledge of this interesting species is only from a short note by Ahmad (1942) and an amplified illustrated description is presented below.

Monœcious, bluish-green, normally forming well-defined rosettes, occasionally crowded and overlapping when the plants are smaller; *thalli* 1–2 times dichotomously branched, 1·5–2·5 mm. long and 1–1·5 mm. broad, often larger, dorsal surface with a prominent median sulcus extending throughout the thallus length, thalli compact with narrow air spaces; *epidermal cells* hyaline, oval or spherical; ventral surface with abundant simple and tuberculate rhizoids, *scales* conspicuous, hyaline or purple, entire, semi-lunar, not extending beyond the thallus margins; *cross-section* of mature thallus 2–3 times as broad as high; sex organs in 2–3 rows along the mid-dorsal line, antheridial papillæ hyaline or pink and projecting above the thallus surface; archegonial neck also projecting above the thallus and after fertilization the lower part becomes golden brown while the upper part remains colourless and collapses; *capsules* in 1–3 rows, exposed in hemispherical depressions; *spore* black and opaque at maturity, outer face 80–134 μ in maximum diameter, regularly reticulate, wall of reticulations very low with the corners projecting slightly resulting in a coarsely dentate or crenate profile, 8–16 reticulations across the outer face, tri-radiate mark very inconspicuous.

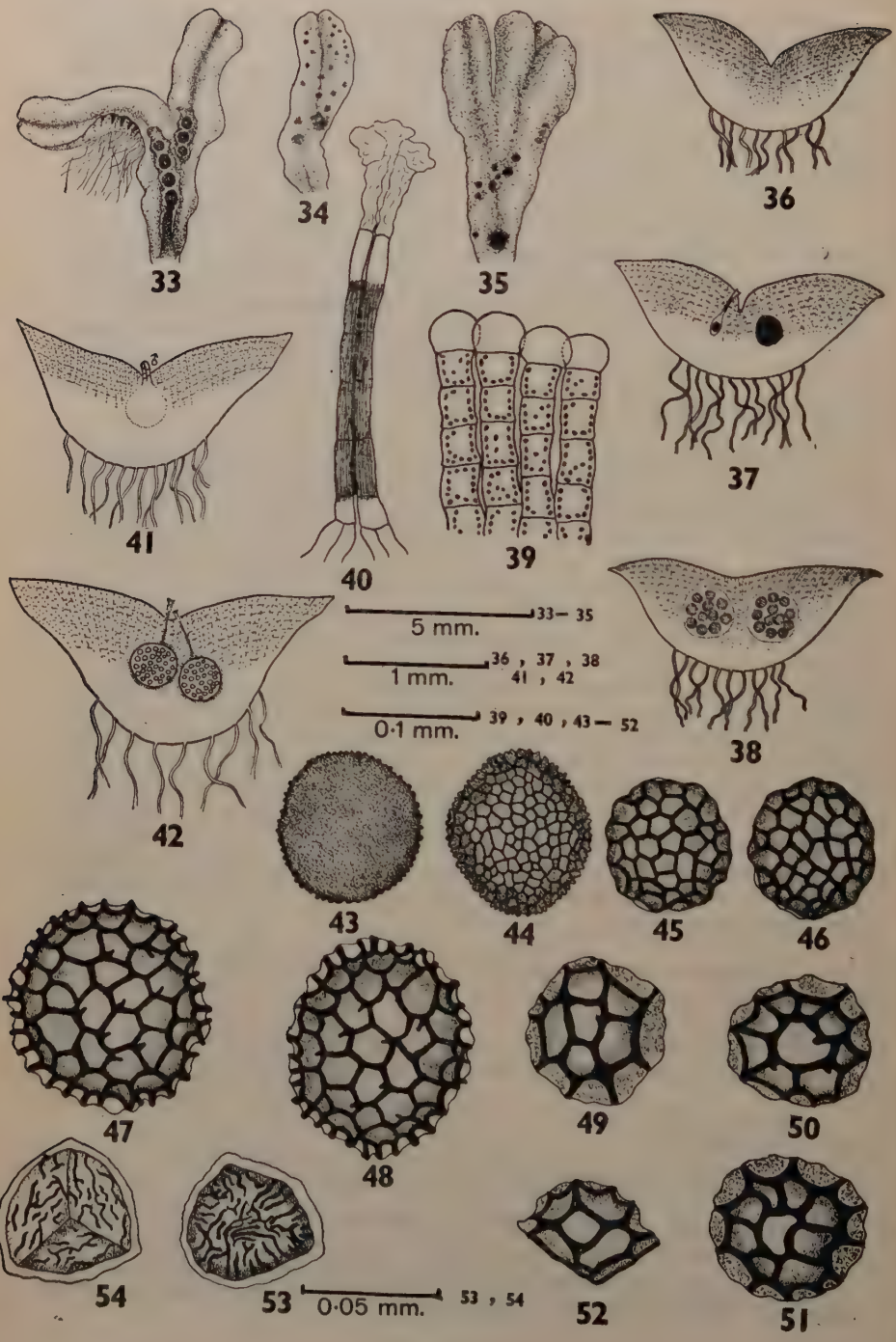
Some specimens occasionally show black fungal perithecia (Text-Figs. 34, 35) as in *R. billardieri*.

This species has recently been observed in association with *R. sorocarpa* in a collection from Spiti, 10,000 ft. (see Udar, 1956).

Riccia crispatula Mitt. *J. Linn. Soc.*, **5**: 127, 1861. Also *Sp. Hep.*, **1**: 25, 1900.

(Text-Figs. 28–32; 49–52; Pl. XXI, Figs. 2–4)

R. crispatula was established by Mitten (1861), on the basis of specimens collected by Gardner from Matale (Ceylon), and he gave a very short and fragmentary account of this species. Subsequently Stephani (1900) presented a somewhat detailed account, based on the


33
34
35
36
37
38
39
40
41
42
5 mm.
33– 35
1 mm.
36 , 37 , 38
41 , 42
0·1 mm.
39 , 40 , 43 – 52
43
44
45
46
47
48
49
50
51
52
53
54
0·05 mm.
53 , 54

Figs. 33–54.

TEXT-FIGS. 33–54. *Riccia gangetica* Ahmad. Fig. 33. A thallus showing the dehiscence of sporophytes. Figs. 34, 35. Thalli showing black fungal perithecia. Figs. 36–38. Cross-sections of a thallus at the apex, in the middle and at the base respectively. Fig. 39. A portion of cross-section of a thallus showing assimilatory filaments and epidermal cells. Fig. 40. Archegonial neck. Figs. 41–42. Cross-sections of a thallus in the middle and at the base of a thallus obtained from xerophytic locality. Figs. 43, 44. Spores, *outer face*. Fig. 45. Spore of *R. discolor* (*R. gollani*, no hb. Levier, 3973, original specimens). Fig. 46. Spore of *R. discolor* (from local specimen). Figs. 47–48. Spores of *R. ballardieri* (*R. bulbifera*, no. 53, ex hb. Berol., type specimens). Figs. 49–51. Spores, *outer face*, of *R. crispatula* (no. 147, ex hb. Kew original spcimens). Fig. 52. Spore, inner face. Same specimens. Figs. 53, 54. Outer and inner faces of the spores of *R. frostii* (*R. microspora*, ex hb. Kew *Leg.*, Griffith).

original specimens, describing some vegetative features as well as the spores.

R. crispatula is apparently endemic to Ceylon as it has not so far been observed in any other country although there is a great possibility of its discovery from India as well as some other tropical countries.

From a morphological investigation of *R. crispatula*, Abeywickrama (1945) doubted that this species is not specifically distinct from *R. billardieri*. This contention, however, does not seem to be valid as the pores of the type specimens of *R. crispatula* (Text-Figs. 49–52) do not answer to *R. billardieri* (Text-Figs. 47, 48; also see Udar, 1957 *a*, Figs. 7, 8). Besides, *R. billardieri* is copiously represented in PANDÉ COLLECTION from Ceylon (4683, 4686) from the locality from which the plants were collected for morphological investigation. In all probability, therefore, the morphological investigation carried by Abeywickrama (1945) deals with *R. billardieri* itself and not *R. crispatula*. Much of this confusion with respect to *R. crispatula* is possibly due to the fact that there is no adequate illustrated account of this species. An attempt has, therefore, been made to fill this gap by the description presented below.

Diœcious, yellowish to dark green, *thalli* crowded and overlapping or isolated, 1–2 times dichotomously branched; *male plants* about 1 mm. broad and upto 5 mm. long; *female plants* larger, 2–3 mm. broad and up to 15 mm. long, compact with narrow air spaces; *midrib ventrally conspicuous*; *rhizoids* simple and tuberculate; *scales* conspicuous, apex rotundate, deep purple, overlapping, somewhat extending beyond the thallus margin; cross-section of mature thallus 1·5–2 times broader than thick in the male thalli and very much broader than thick in the female thalli, *abruptly winged*, *wings extremely narrow and thin*; *sex organs* in 1–2 rows, antheridial papillæ pink, projecting above surface; *capsules* usually in a single row, exposed in hemispherical depressions by the decay of the overlying tissues; *spore* dark brown, *tetrahedral*, 65–90 μ across the outer face, reticulate, 3–5 large reticulations across the outer face, similarly reticulate on the inner faces, corners of the walls of reticulations greatly extended into a thin membranous border which is hyaline and its surface greatly eroded.

Specimen examined.—No. 147. *Hab.* Ceylon, Matale. *Leg.* Gardner. ex herb. Kew. (A portion of original specimens.)

All the four species discussed above intergrade in their vegetative characters often in such a way that definite identification could only be obtained by an examination of specimens with the spores. The key presented below will serve to simplify their separation and identification:—

Terrestrial; thalli non-ciliate; compact with narrow air spaces; scales persistent, large and deeply pigmented.

1. Diœcious .....3.

2. Monœcious .....4.

3. (*a*) Spores *tetrahedral*, tri-radiate mark inconspicuous, 80–120 μ, with 6–10 reticulations across the outer face, inner faces more or less similarly reticulate as the outer..... *R. discolor.*

   (*b*) Spores *tetrahedral*, tri-radiate mark prominent, 65–90 μ, with 3–5 large reticulations across the outer face, walls of reticulations at angles extending into a membranous border....*R. crispatula.*

4. (*a*) Thallus usually 2–3 times as wide as thick; spores dark brown turning *black and opaque at maturity*, 90–130 μ, with 8–16 small reticulations across the outer face, surface beset with coarse papillæ from the angles of reticulations.....*R. gangetica.*

   (*b*) Thallus usually 4–6 times as wide as thick, spores reddish brown, 80–150 μ, with 5–7 reticulations across the outer face, angles of walls of reticulations drawn out into prominent projections capped by a thin undulating membrane.....*Riccia frostii* Aust.
   R. billardieri.

Syn.: *R. microspora* St. *in Sp. Hep.*, **1**: 43, 1900.

R. sanguinea Kash., *in J. Bombay nat. Hist. Soc.*, **24**: 343–350, 1916.

(Text-Figs. 53, 54; Pl. XXI., Fig. 5)

The first undoubted record of *R. frostii* from India is the one in the posthumous memoirs of Griffith (1849 *a*: p. 346; 1849 *b*: Pl. XXV, Fig. f) who described and figured an unidentified diœcious species collected by him from the shores of the Brahmaputra in Assam. The illustrations and the descriptions given by Griffith (*l.c.*) correspond closely to *R. frostii* and the two are certainly the same. Subsequently Stephani (1900) instituted *R. microspora* based on a collection of Kurz

from the banks of the Ganges, Bengal and this species is also identical with *R. frostii.*

Two specimens referred to as *R. microspora* St., one collected by Griffith from upper Assam and the other collected by Montier from Tonkin, were examined from Stephani's Herbarium and although only female plants are represented in these collections they are fertile and could thus be properly studied. Specimens from Griffith's collection certainly resemble *R. frostii* both in vegetative characters as well as the spores (Text-Figs. 53, 54; Pl. XXI, Fig. 5) and the specimens from Tonkin are also absolutely similar.

Both *R. frostii* and *R. microspora* have been placed by Stephani (1900) in the same section of his classification and both are dicœcious. Only minor vegetative differences seem to have been recognized as specific for *R. microspora* which certainly do not warrant the establishment of a new species on account of their well recognized variability under ecological conditions. The only significant difference between the two species seems to be the size of the spores which are smaller in *R. microspora* in being 30 μ. A measurement of the spores, from the specimens obtained from Stephani's Herbarium, does not agree with that given by Stephani (1900). They are larger and average 40–55 μ well within the limits of the spore size in *R. frostii.* In spore sculpturing *R. microspora* (Text-Figs. 53, 54) is certainly identical with *R. frostii.* The two species are thus identical and *R. microspora* St. has been reduced as a synonym of *R. frostii* Aust.

Kashyap (1916) instituted a new species, *R. sanguinea,* which has also been shown to be definitely identical with *R. frostii* (see Udar, 1957 *a*).

R. frostii is a cosmopolitan species and detailed accounts occur in several taxonomic contributions along with two detailed morphological accounts by Black (1913) and Pandé (1924).

Summary

1. Indian species of *Riccia* from Stephani's Herbarium, obtained through the courtesy of Dr. C. E. B. Bonner, have been investigated as several of them could not be collected from the country in spite of repeated attempts and also with a view to ascertain their specific identity.

2. The specific status of *R. gollani* Lev., *R. bulbifera* St., and *R. microspora* St. has been discussed and it has been shown that *R. gollani* Lev. is a synonym of *R. discolor* L. *et* L., *R. bulbifera* St. is a synonym of *R. billardieri* Mont. *et* N. and *R. microspora* St. is a synonym of *R. frostii* Aust.

3. *R. crispatula* Mitt. is an authentic species and the earlier doubt about its specific identity with *R. billardieri* has been shown to be not valid. This species is apparently endemic to Ceylon but there is

sufficient chance of its being discovered from India and other tropical countries.

4. Detailed illustrated taxonomic account of *R. discolor*, *R. billardieri*, *R. gangetica* and *R. crispatula*, and a key for their identification, has been given as no authentic complete accounts of these species are available. Of these four species, *R. discolor* and *R. crispatula* are diœcious and the other two are monœcious.

Acknowledgements

The authors express their deep sense of gratitude to the Scientific Research Committee, Uttar Pradesh, for a part of grant utilized in this work, to Dr. C. E. B. Bonner, Conservatoire Botanique, Genève, for kindly supplying us specimens of *R. gollani* Lev., *R. bulbifera* St., *R. microspora* St., *R. crispatula* Mitt. and *R. discolor* L. *et* L. from Stephani's Herbarium; to Dr. Herman Persson for pencil tracings of Stephani's unpublished drawings and to Dr. W. Meijer for specimens of *R. billardieri* Mont. *et* N. from Herbarium Bogoriense, Java, and to numerous friends all over the country for sending us specimens of *Riccia*.

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EXPLANATION OF PLATE XXI

(Figs. 1–6)

FIG. 1. *R. discolor* (*R. gollani*, no. hb. Levier, 3973, original specimens), ×3.

FIGS. 2–4. *R. crispatula* (No. 147, ex hb. Kew, original specimens), ×3. Figs. 2, 3. Female thalli. Fig. 4. Male thallus.

FIG. 5. *R. frostii* (*R. microspora*, ex hb. Kew, *Leg.*, Griffith)., ×3.

FIG. 6. *R. billardieri* (*R. bulbifera*, No. 53, ex hb. Berol., type specimens) showing tubers, ×5.

CULTURE STUDIES IN THE GENUS *RICCIA* (MICH.) L.

II. Sporeling Germination and Regeneration in *R. crystallina* L.*

By Ram Udar

Department of Botany, Lucknow University, Lucknow

(Received for publication on September 10, 1957)

Introduction

Vegetative reproduction and regeneration as a means of reproduction among the Bryophytes is a frequent phenomenon. Cells of gametophyte and sporophyte show great regeneration potentiality particularly among the Mosses and a large number of workers have added to our knowledge of this interesting aspect of study along with the sporeling germination in this group. Among the hepatics, while a great amount of work has been done on the sporeling germination, regeneration studies have been mainly restricted to leafy genera. In a recent paper Fulford (1956) has very ably discussed and reviewed the sporeling and regeneration patterns in this group of Hepaticæ but the thallose hepatics apparently seem to have received very little attention in the study of regeneration patterns.

In an earlier communication of this series Udar (1957) described the sporeling germination in *Riccia billardieri* Mont. *et* N., a common monsoon species belonging to the Euriccia section of the genus. It was observed that (*a*) in culture there is no rest period required for germination, (*b*) during germination the spore increases in size by absorbing moisture and a prominent pore is formed on the outer face of the spore opposite the tri-radiate mark, (*c*) the germ tube laden with the food material emerges through this germ pore, (*d*) the first rhizoid arises from the base of the germ tube as its continuation and is not separated from it by a septum and (*e*) a two-sided apical cell is formed rather early in development and is responsible for the growth of the germling in early stages. In order to ascertain whether these observations are likely to prove constant in the genus and have some phylogenetic significance the study has been extended to some more species. The present communication deals with sporelings and regenerants in *R. crystallina* L.

Material and Methods

Specimens of *R. crystallina*, bearing mature sporophytes, were collected from the Experimental Farm of the Department and the compound of the local Isabella Thoburn College. This species very often

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* Contribution from the Department of Botany, Lucknow University, India, New Series, No. 30.

grows in association with *R. cruciata* Kash. but under favourable conditions large tracts of land are predominantly covered by luxuriant growths of *R. crystallina* alone. However, the characteristic external appearance of the two species, when growing together, helps to separate them in nature without any chance of confusion.

R. crystallina is monœcious and usually forms well-defined rosettes (Plate XXII, Fig. 1). Numerous mature sporophytes, prominently bulging on the ventral surface, are seen during November-December. The mature spores are dark brown, 60–85 μ in the maximum diameter, reticulate with large incomplete reticulations on the outer face, prominently winged, wing 8–12 μ wide, wing margin densely crenate; tetrahedral and with the tri-radiate mark prominent (Text-Figs. 1, 2). Occasionally the wing is considerably reduced.

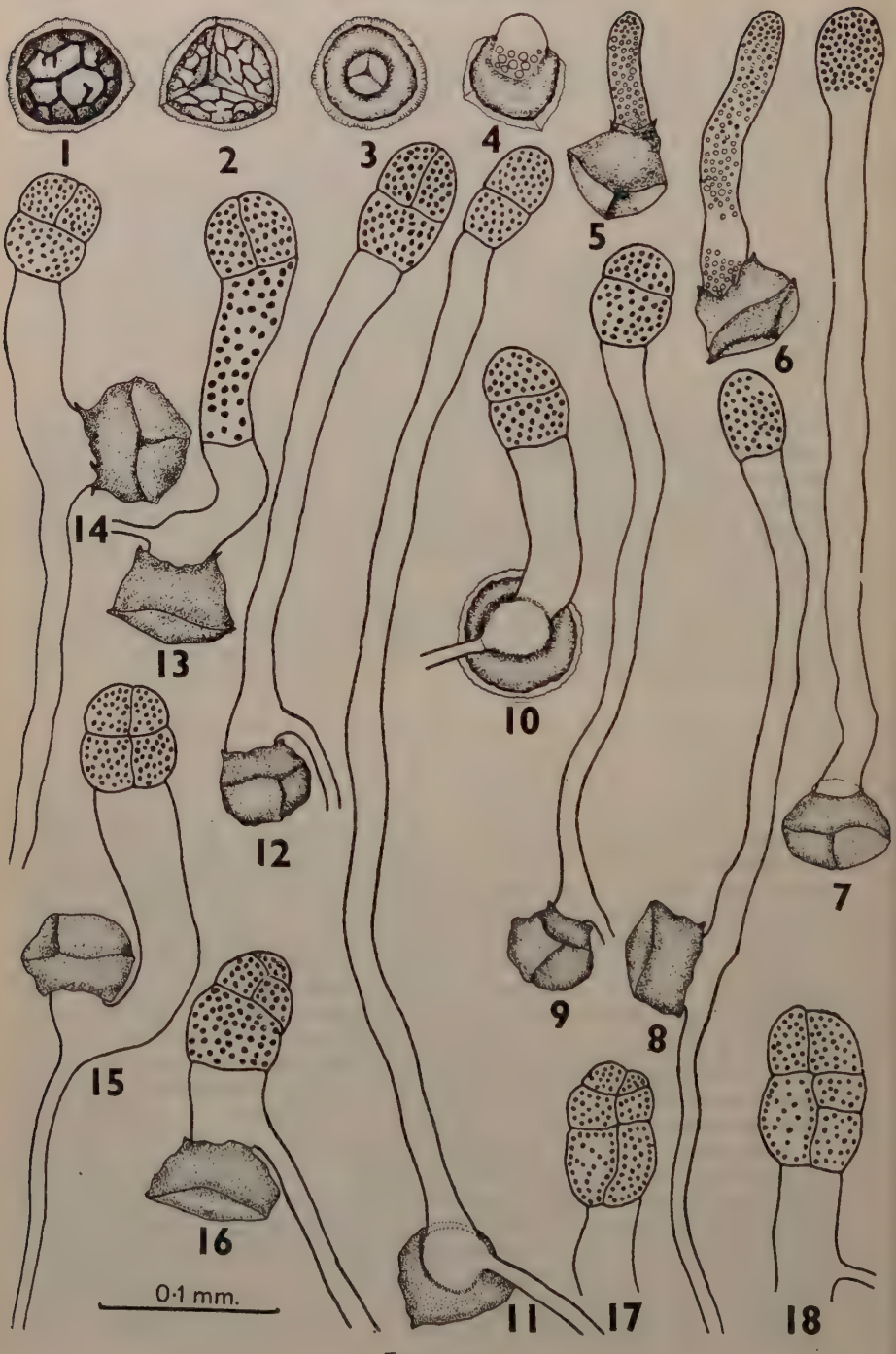
Unruptured mature sporophytes were carefully taken out of the thallus and repeatedly washed with sterile water to avoid chances of contamination of the cultures with the algal and fungal growths associated with the plants in nature. The cultures were made as in the case of *R. billardieri* (Udar, 1957). The pots, the soil and the water used for the cultures were sterilized in an autoclave at a pressure of 15 lbs. for 15 minutes.

For regeneration intact thalli and pieces of thalli were kept in humid chambers and in about 2–3 weeks profuse regeneration was noticed showing several stages.

Observations

Sporeling Germination

There is apparently no rest period required as the spores collected on November 14, 1956, and cultured the same day, germinated in about 6–10 days. Prior to germination the spores absorb enough moisture and there is an evident increase in size by about 10–20 μ. This, however, does not indicate that the spores undergoing swelling would necessarily germinate as many of them merely absorb water and do not germinate at all. The viability, approximately, is in the neighbourhood of 90%. The spores later become more or less transparent followed by the formation of a *prominent pore opposite the tri-radiate mark* (Text-Fig. 3). *The germ tube emerges through this pore* (Text-Fig. 4). These two characters seem to be constant in the genus as similar behaviours have also been observed in the case of *R. cruciata, R. discolor, R. gangetica* and *R. melanospora* (Udar, unpublished). The germ tube (Text-Fig. 4) at this stage is laden with food material. There is an elongation of this tube and subsequent appearance of chloroplasts which aggregate in greater numbers towards the tip which bulges out prominently (Text-Figs. 5–7). In the same culture the germ tube may elongate considerably becoming narrow (Text-Figs. 7–9; 11, 12) but often it remains much shorter and broader (Text-Figs. 10; 13–18). The frequency in the differential behaviour in the relative elongation of the



FIGS. 1–18.

TEXT-FIGS. 1–18. Fig. 1. Spore (outer face). Fig. 2. Spore (inner faces). Fig. 3. Germ pore on the outer face of the spore opposite the tri-radiate mark. Fig. 4. Emergence of the germ papilla. Figs. 5, 6. Elongation of the germ tube. Fig. 7. Aggregation of the chloroplasts at the tip of the germ tube. Fig. 8. Formation of one-celled germ plate. Figs. 9–11. Two-celled germ plate. Figs. 12–14. Three-celled germ plate. Fig. 15. Four-celled germ plate. Figs. 16–18. Further stages in the germlings. (For details see the text.)

germ tubes is nearly equal. The factors, both external and internal, which determine such a behaviour await further study.

A transverse septum near the apical part of the germ tube separates the first cell of the germ plate (Text-Fig. 8) which subsequently divides transversely into two cells (Text-Figs. 9–11). In one case (Text-Fig. 13) the first cell formed at the tip showed a considerable elongation. The second division which is vertical occurs in the upper of the two cells (Text-Figs. 12–14) followed by a similar division in the lower cell as well (Text-Fig. 15). Subsequently a two-sided apical cell is established which, by its activity, contributes to the growth of the young gametophyte in early stages (Text-Figs. 16–18).

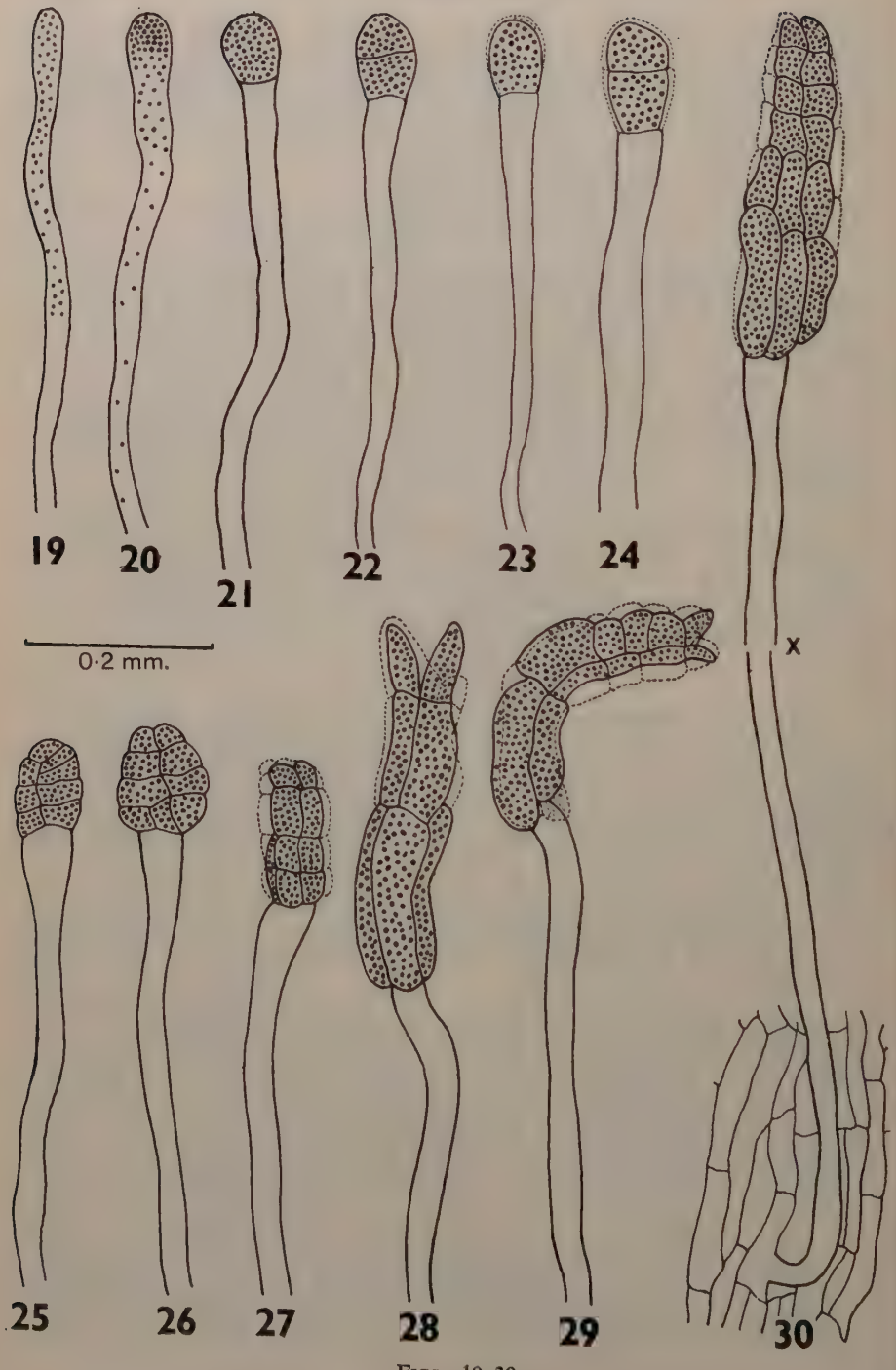
The first rhizoid arises early when the germ plate is one-celled (Text-Fig. 8) and is a continuation of the germ tube being not separated from it by a septum (Text-Figs. 8–16, 18) resembling in this respect *R. billardieri* described earlier (Udar, 1957). Apparently *this character seems likely to prove constant in the genus.*

REGENERATION

The term regeneration, according to Fulford (1956), has been ascribed to the activities "which bring about the formation of a new plant from a single cell which is in a position to and usually does perform some other functions" and the regenerant "is a plant which has developed through regeneration from a presumably adult cell which has undergone dedifferentiation back to an activated condition which then initiates cell multiplication of one sort or another. The stages in the development of the regenerant may be a repetition of the stages of development of the sporeling and gemmaling, or one or more of these stages may be missing or the pattern of development may be entirely different."

Intact thalli as well as pieces of thalli of *R. crystallina* were placed in humid chambers and in about 2–3 weeks profuse regeneration was observed (Plate XXII, Figs. 2–4). Effective regeneration is also said to occur by the application of hormones such as indole-3-acetic acid, B-(indole-3)-propionic acid, B-(indole-3-)-*n*-butyric acid and 2, 4-dichlorophenoxyacetic acid (see Fulford, 1956). An attempt is being made to study the effect of these substances on regeneration patterns in *Riccia.*

The dedifferentiated cells, on the ventral surface or the margin of thalli, become papillate and elongate considerably (Text-Fig. 19; Plate XXII, Fig. 1 *a*). Later chloroplasts make their appearance and aggregate towards the tip which bulges out prominently



FIGS. 19–30.

TEXT-FIGS. 19–30. Fig. 19. Elongation and subsequent appearance of chloroplasts in a dedifferentiated cell from the ventral surface of the thallus. Fig. 20. Aggregation of the chloroplasts in the tip of the same. Fig. 21. Separation of the first cell of the regenerant. Figs. 22, 23. Two-celled regenerant. Fig. 24. Four-celled regenerant. Figs. 25–29. Further stages in regeneration. In Fig. 25 an apical cell is clearly noticeable. Fig. 30. Continuity of the dedifferentiated cell into the long tube bearing the regenerant terminally. At *x*, the long tube broken.

(Text-Fig. 20; Plate XXII, Fig. 1). A transverse septum is then laid down near the tip forming an 1-celled plate (Text-Fig. 21; Plate XXII, Figs. 2, 4 *b*). The second division may be vertical or transverse (Text-Figs. 22, 23) forming a 2-celled plate. A 4-celled plate is subsequently formed (Text-Fig. 24). Later an apical cell is organized (Text-Fig. 25) as in the sporelings which contributes to the growth of the young regenerant (Text-Figs. 26–30; Plate XXII, Figs. 2–4).

In *Riccia* the earliest record in regeneration, as far as the author is aware, is that in *R. glauca* L. by Fellner (1875) who observed somewhat similar stages in regeneration as in *R. crystallina* and interpreted them to have originated by the transformation of rhizoids. This view is evidently not valid and the misconception about the origin of the regenerants can clearly be attributed to the fact that long tubes, bearing the regenerants, were mistaken for rhizoids.

It would thus appear that the basic developmental patterns of the sporelings and the regenerants in *R. crystallina* are similar. In both there is the formation of a tube which elongates, depending on culture conditions, followed by terminal segmentations, further growth in early stages being governed by the establishment of a two-sided apical cell.

SUMMARY

1. Sporeling germination and regeneration in *R. crystallina* L. have been described.

2. The formation of a germ pore opposite the tri-radiate mark on the outer face of the spore, during spore germination, and the emergence of the germ tube through this pore seem likely to prove constant in the genus *Riccia*.

3. The first rhizoid arises as a continuation of the germ tube and is not separated from it by a septum. This character, too, is likely to prove constant in all the species of *Riccia*.

4. Profuse regeneration occurs from intact or pieces of thalli kept under humid conditions.

5. Both the sporelings and the regenerant broadly follow a similar pattern of developmental stages.

ACKNOWLEDGEMENTS

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Explanation of Plate XXII

(Figs. 1–4)

FIG. 1. A well-formed rosette of *R. crystallina.*

FIG. 2. An intact segment of the thallus bearing regenerants. (*a*), an elongated dedifferentiated cell; (*b*), one-celled regenerant.

FIG. 3. Regeneration from a piece of thallus. (*r*), young stage showing the formation of rhizoid.

FIG. 4. Regeneration from a thallus piece. (*b*), 1-celled regenerant and also some advanced stages. (*c*), a regenerant subtended by a very long tube.

1 mm 1 0·8 mm 3,4

Ram Udar

VEGETATION TYPES OF INDIA*

(Summaries of Papers read at the Symposium held under the auspices of the Indian Botanical Society during the Baroda Session of the Indian Science Congress, 1955)†

A Discussion on the Climatic Climax Community in Central India

By C. E. Hewetson

Mixed deciduous forest is dominant over the greater part of the area except where 'Sal' is present. Broadly speaking the west of the area is covered by trap rocks and the east by archæan gneisses and granites. A number of other rocks also appear. The forest soils are mostly tropical red earths but the soils derived from Gondwana sandstones are usually deficient in minerals. In valleys and some other areas black cotton soil or 'regur' occurs which is deprived of the forest owing to their value for agriculture. An examination of the climate reveals that frost is not a very important factor. In the mixed deciduous forests some 150–300 species of trees, shrubs and climbers have been recorded. The local floristic variations in the vegetation may be due to soil, historical and chance factors. The occurrence of more widely distributed species is not controlled by edaphic factors. Biotic influences are so widespread that it is difficult to find any area representing climatic climax. Comparatively speaking therefore, the Government reserved forests are most suitable types for such study. From the working plans of such forests 68 tree species, 17 woody shrubs and 10 woody climbers have been selected to study their distribution in 20 divisions of the forests of the Madhya Pradesh. Three main groups of the divisions, as those on trap soils with teak, those in the central area without teak or sal and the eastern area mostly on Cuddapahs and older crystalline rocks with 'Sal' are recognised. A study of the frequency distribution of the species in the 20 divisions shows that the mixed deciduous forests can be best distinguished as *Anogeissus Terminalia* Mixed Deciduous or 'Combretacetum' Mixed Deciduous.

Teak and 'Sal' are the most important trees in the forests. 'Sal' forms upto 95% of the crop with *Terminalia tomentosa.* Its distribution is controlled by rainfall and soil. It may be accepted as a climatic climax which has ousted the older mixed deciduous. Teak on trap soils flourishes due to biotic causes. In natural forests it forms a small proportion of the crop.

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General Features of the Lower and Middle Hill Forests of East Nepal

By M. L. Banerji

Observations were made in the dry months of April, May and June. Average annual rainfall of Kathmandu is about 100″. 'Sal' forests, mixed dry forests and their variations on the ridges and dense forests in ravines on higher altitudes are common. The absence of a true mixed wet forest is noteworthy. The important species of each of the three types are:—

1. 'Sal' forests: *Shorea robusta*, *Phœnix humilis*, *Emblica officinalis*, *Dillenia pentagyna*, *Kydia calycina*, *Semecarpus anacardium*, etc.
2. Mixed dry forests: *Rhus parviflora*, *Aegle marmelos*, *Woodfordia fruticosa*.
3. Humid valley forests: *Holarrhena antidysenterica*, *Beaumontia grandiflora*, *Ehretia acuminata*, *Ostodes paniculata*, *Mallotus philipinensis*, *Macaranga pustulata*, *Albizzia lucida*, *Bassia butyracea*, etc.
4. The middle hill forest between 3,000–6,000 feet presents a bioedaphic community on account of intensive cultivation. The main species are: *Schima wallichii*, *Andromeda ovalifolia*, *Mæsa chisia*, *Eurya symplocina*, *Rhododendron arboreum*, etc.
5. Riverain forests are constituted of *Pyrus pashia*, *Castanopsis tribuloides*, *Quercus lancæfolia*, *Eurya symplocina*, etc.

Observations on the Vegetation of the Rampa and Gudem Agency Tracts of the Eastern Ghats

By R. Seshagiri Rao

The forests of the Rampa and Gudem Agencies located along the Eastern Ghat ranges of the East Godavari and the Vishakhapatnam districts of the Andhra State (Long. 81° 30′–82° 15′ and Lat. 17° 15′–18°) have been very little explored. The vegetation of this area with an average rainfall of 40–50 inches can be divided into three major zones, namely, (i) the Arid Scrub Zone (from the 100-foot-contour to the 500-foot-contour), (ii) the Transitional Zone mixed with cultivated lands (from the 500-foot-contour to the 1,000-foot-contour) and (iii) the Deciduous Forest Zone (from 1,000-foot-contour upwards). The first two zones comprise mostly arid, scattered, thorny, scrub jungle with many xerophytic species. The deciduous forest zones comprises the dry-deciduous forest ranging between 1,000–3,000 feet (300–910 m.) altitude, and the moist deciduous forest from 3,000 feet (910 m.) upwards. *Xylia—Terminalia—Anogeissus—Dendrocalamus* association predominates in various parts of the region under study. Most of the

hill tops of the various ranges present beyond 4,000 feet (1,220 m.) altitude, a characteristic bald appearance with no tree-growth and are covered by dry weathered rocky boulders, allowing stunted growth of a few shrubs and herbs. The Gudem Valley at an altitude of about 3,000–3,500 feet (910–1,070 m.) develops one of the most dense primeval, unreserved forests of the area with a few pockets of highly humid, dark corners presenting almost semi-evergreen type of vegetation where several Himalayan species of *Lycopodium*, *Gleichenia*, *Botrychium*, *Alsophila*, *Peperomia*, *Pygeum*, *Curculago* and a few other sub-tropical and temperate species have been collected. The region along the Ganga-Devi Ghat also presents similar primeval forests, with patches of almost semi-evergreen type of vegetation. Occurrence of *Nyctanthes arbor-tristis* and essential oil grass species of *Cymbopogon* in wild condition covering large tracts of the hill slopes is one of the interesting features of the vegetation worth studying in detail.

Several species belonging to such distant regions like the Himalayas, Assam, Burma and the Andamans have been newly recorded from this area and this indicates the necessity of exploring vast tracts of India for the many unknown species and their newer localities. Various aspects of the region and its vegetation, such as geology, climate, biotic factors, vegetable resources of the area, types of forests and their floristic composition and frequency of families have been recorded along with an enumerated list of about 800 species.

Ecological Studies on the Vegetation of Jodhpur Tehsil

By Shanti Sarup and L. N. Vyas

The climate is characterized by a low annual rainfall, extremes of temperature, low precipitation and therefore low relative humidity. These features are further aggravated by high wind velocity and dust and thunder-storms.

The soil is sandy and has low water content. It is fairly rich in carbonates, chlorides and exchangeable bases like Mg, Ca and K. It is usually deficient in nitrates. The hydrogen-ion concentration is on the alkaline side and ranges from 7 to 9·5.

Animals and human beings have great disturbing influence on the growth of vegetation. A variety of animal and fungus pests destroy the vegetation.

It is concluded that the vegetation of the investigated area has the potentialities of development into a climax of thorn forest but the greatest drawback is the low water content of the soil.

The principal species of the different communities are given below:—

1. Hills: Pure stands of *Euphorbia royleana* and mixed with *Zizyphus rugosa*, *Opuntia dillenii*, *Grewia populifolia*, *Asparagus racemosus*, *Abutilon indicum*, etc.

2. Undulating land: *Euphorbia royleana, Prosopis juliflora, Capparis aphylla, Gymnosporia montana,* etc.

3. Plains: *Gymnosporia montana, Capparis aphylla, Acacia rupestris, Leptadenia spartium, Tephrosia purpurea, Gynandropsis pentaphylla, Solanum xanthocarpum, Argemone mexicana,* etc.

4. Sand-dunes: *Capparis aphylla, Calligonum polygonoides, Crotalaria burhia, Aerua tomentosa, Calotropis procera, Leptadenia spartium, Gymnosporia montana, Ephedra foliata,* etc.

5. Dry rocky stream beds: *Cryptostegia grandiflora, Sesbania ægyptiaca, Hygrophylla longifolia, Achyranthes aspera, Boerhaavia diffusa,* etc.

6. Saline river-bed: *Tamarix dioica, T. gallica, Pluchea lanceolata, Suæda fruticosa,* etc.

7. Dry pond bed: *Polygonum plebejum, Potentilla desertorum, Marsilea quadrifolia, Coldenia procumbens, Heliotropium indicum,* etc.

8. Aquatic: *Eichhornia crassipes, Potamogeton crispus, Hydrilla verticillata, Vallisneria spiralis, Ceratophyllum demersum,* etc.

Ecology of Forest Types Bordering Rajasthan and Uttar Pradesh about the District of Agra

By S. Sinha and K. C. Basu-Chaudhary

The general features of the vegetation are chiefly in adaptation to dry climatic conditions prevailing for about nine months of the year, but the variation in the vegetational types is determined by edaphic and topographical factors. Biotic factors such as grazing and cutting of wood for fuel in the already thin forest have profoundly influenced the forest formations. Following mainly Champion's (1936) classification of the forest types of India the main communities recognised in the area are (i) Desert thorn forest, (ii) *Acacia* scrub forest, (iii) *Anogeissus* forest, (iv) Saline scrub forest, (v) Ravine scrub and (vi) Usar land scrub. The principal species of each of these are noted below:—

1. Desert thorn forest: *Salvadora oleoides, Capparis aphylla, C. sepiaria, Zizyphus rugosa, Z. jujuba, Acacia senegal, Dichrostachys cinerea, Celastrus paniculata, Grewia orbiculata, Guazuma tomentosa, Clerodendron phlomidis,* etc.

2. *Anogeissus* forest: *Anogeissus pendula, Balsamodendron mukul, Guazama tomentosa, Butea monosperma,* etc.

3. *Acacia* scrub forest: *Acacia arabica, A. senegal, A. leucophlœa, Prosopis spicigera,* etc.

4. Ravine scrub forest: *Capparis aphylla, Carissa spinarum, Balanites roxburghii, Zizyphus jujuba, Prosopis spicigera, Acacia leucophlœa, A. arabica,* etc.

5. Saline scrub: *Salvadora oleoides,* etc.

6. Usar land scrub: *Acacia senegal, A. arabica, Capparis aphylla,* etc.

The Relict Vegetation of Sheo Bari, Sohan Valley

(Hoshiarpur Siwaliks)

By G. S. Puri

The average annual rainfall is 57·17″ and the soil in the valley is a recent alluvium. While the vegetation in the valley is scrubby, consisting of early riverain species like *Acacia catechu, Dalbergia sissoo,* the vegetation at Sheo Bari is mesophytic, having *Putranjiva, Albizzia lebbek, Litsea chinensis,* etc. The course of succession in the Sohan Valley has been studied and it is suggested that the mesophytic vegetation may exist in a stable equilibrium in the valley, provided the adverse human interference is excluded.

The Ecology of Sal (*Shorea robusta* Gaertn. f.) in Madhya Pradesh

By G. S. Puri

Champion's three main types of 'sal' in Madhya Pradesh have been studied with a view to determ ne the exact relationship of the 'sal' crop with the edaphic factor. The floristic composition of the types and their successional status in relation to climate and soil have been studied. A study of ecological factors has necessitated the subdivision of Champion's moist type into four sub-types. The floristics, successional status and geology and soil conditions are interesting. A significant negative relationship between the quality of 'sal' crops and exchangeable calcium has been observed not only in the upper layers of the soil but in the whole profile. Thus champion's B2 (*c*) type with good 'sal' regeneration has been shown to have a lower amount of calcium in the whole profile and B2 (*a*) type which is C.P. III to IV quality mixed 'sal' forest, to have the highest amount. A correlation is also seen between the forest communities and soil loss on ignition. The absence of a correlation of pH in surface soil has been inferred as due to fire, grazing and other biotic interferences which are almost uniform in all the forest types. The indications from the soil study have been confirmed by foliar analysis to show that good quality 'sal' forest thrives best on non-calcareous soils with low exchangeable calcium. The practical importance of this study in forestry has been indicated.

Teak-Bearing Forests of Madhya Pradesh

By K. K. Bhatia

Teak forests of Madhya Pradesh are usually of mixed composition. However, as a result of selective fellings, purity of the teak crop is established in many cases.

In Madhya Pradesh teak-bearing forests are well included in (1) Southern Indian moist deciduous forests as exemplified by the forests of Bori and Allapalli. (2) Dry teak forests found over the greater portion of the State.

Besides, the dry mixed miscellaneous forests may also contain a small portion of teak, usually near the transition zone.

Phytosociological and floristic studies along with studies of environmental factors as climate, physiography, soils and biotic influence have been made.

The types described in this paper are characterised mainly by the co-dominant species as given below:—

Moist teak forest

1. Allapalli (South Chanda Div.) ..	(*a*) Teak-Bamboo forest (*b*) Mixed teak forest (*c*) Teak-*Cheistanthes* forest
2. Bori (Hoshangabad Div.) ..	(*a*) Teak-Bamboo forest (*b*) Teak *Lantana* forest (*c*) Mixed teak forest
3. Hirdaygarh (Chindwara Div.) ..	(*a*) Mixed teak forest

Dry teak forest

1. Nimar Division (Punnasa and West Kalibhet Ranges) ..	(*a*) Teak-*Hardwickia* forest (*b*) Mixed teak forest (*c*) Teak-*Boswellia* forest (*d*) Mixed teak forest
2. Kheli range (Hoshangabad Div.)	(*a*) Mixed teak forest
3. Sagar Division—	
(A) Ramna ..	(*a*) Teak-Bamboo forest (*b*) Mixed teak forest (*c*) Teak-*Anogeissus pendula* forest
(B) Hirapur, Shahgarh ..	(*a*) Teak-*Boswellia* forest
(C) Ghatera	(*a*) Mixed teak forest (*b*) Teak-*Boswellia-Sterculia* forest
(D) Patharia forest ..	(*a*) Mixed teak forest.

Successional trends indicate that the climax community at Patharia includes *Tectona grandis*, *Terminalia tomentosa* and *Diospyros melanoxylon*.

Some of the types described are confined to definite range of habitats. However, with changes in the environmental conditions brought about by excessive biotic exploitation, the characteristic species get eliminated and seral stages develop, some of which are represented by mixed miscellaneous teak forest.

The Ecological Status of Grasslands of India

By R. O. Whyte, P. M. Dabadghao and S. V. Venkataraman

Although the forests of India have been classified and mapped, the grasslands have not received similar attention. Apart possibly for certain high alpine zones, it appears that grassland does not occur as a climax formation in India; merely as a sub-climax in association with different forest climaxes. A proper understanding of the types of grassland is complicated by the influence of the biotic factors, grazing, burning and cutting; on the whole tree/grass relationships. Variations in intensity of these factors have produced a large number of grassland types showing different stages of deterioration and regression. There are indications that there may perhaps be not more than about eight major grassland sub-climax types from which the multiplicity of regression types have evolved.

The Government of India in association with FAO is now undertaking a Grassland Survey of India, employing a team of six grassland ecologists and foresters over a period of three to five years. The team will map by rapid reconnaissance methods adapted to the great area to be covered. Grassland types will be related to associated climax or regressive forest types. The data collected will be of great economic importance in the agronomic work of discovering how best to manage the grassland areas for livestock grazing and feeding.

Grassland Types of Sagar, Madhya Pradesh

By S. C. Pandeya

The investigations are based upon the grasslands lying in the suburb to the east of the city of Sagar, Madhya Pradesh. The area is characterised by undulating plateaux. Cultivation and grazing are effectively shaping the grassland communities. However, the hay plots are kept fenced. A total area of 30 sq. miles of grasslands around the University of Saugar plateau has been studied.

The climate of Sagar is markedly periodic with adequate precipitation which is capable of supporting a mixed dry deciduous type of forest. It is obvious, therefore, that the present status of the grassland communities is so maintained by anthropogenic factors.

Eight grassland associations have been distinguished and named after their dominant species. These are classified according to Gleason (1927), on the basis of apparent floristic homogeneity, definite limits to the area occupied and duration in time.

The eight associations are correlated with soil types. Soil moisture and exchangeable calcium seem to govern the distribution of the associations to great extent. The underlying rocks are basaltic (Deccan Trap) with intertrappean beds (impure lime) and intercalations of ashes. Geological erosion leads to laterisation of the weathered mass. On transportation the laterised product mixes up with intertrappean lime and forms lime rich dark loam downslopes. Calcification of this soil leads to maturity. Local variations in soil characters and subsequently in composition of grasslands are due mainly to topography and biotic factor.

The Principal Grassland Types and Other Grass Habitats of Uttar Pradesh

By S. K. Seth

Part I.—The following thirteen types of grasslands in Uttar Pradesh have been recognised on the basis of primarily physical or physiological moisture relations of the soil and secondarily dominant species.

Xerophytic grasslands

A. Physically dry soils—

1. Texturally dry soils in moist regions
   (i) *Aristida—Neyrandia* associes
   (ii) *Chrysopogon—Eulaliopsis* associes
2. Soils of dry and arid regions
   (i) Dry scrub and ravine grasslands
   (ii) *Themeda—Sehima* associes

B. Physiologically dry soils

(i) In moist regions—clayey waterlogged soils. *Saccharum—Vetiveria* associes

(ii) In drier regions—alkaline soils. *Sporobolus—Chloris* associes

C. Alpine meadows

Mesophytic grasslands

D. Himalayan thick parklands

E. Moist Savannahs

1. High alluvium savannah
   (i) *Narenga* associes
   (ii) *Saccharum—Themeda—Vetiveria* associes
2. Low alluvium savannah
   (i) *Erianthus munja* associes
   (ii) *Erianthus ravennæ* associes

Hydro-Mesophytic grasslands

F. Reed swamps: *Phragmites—Arundo* associes

In addition to the regular grasslands, the following two more groups of habitats are included.

I. Forest habitats, chiefly:
   A. Dry 'sal' forests
      (i) Dry siwalik 'sal'
      (ii) Dry alluvial 'sal'
   B. Moist 'sal' forests
      (i) Moist western hill 'sal'
      (ii) High level alluvial 'sal'
      (iii) Low level alluvial 'sal'
      (iv) Old alluvium 'sal'
      (v) West tarai 'sal'
   C. Subtropical chir pine forests
   D. Temperate moist 'deodar' forests
   E. Western temperate mixed conifers and oak-fir forests
   F. Himayalan oak forests
   G. Dry bamboo brakes

II. Special habitats:
   A. Closed forests and forest margins
   B. Moist habitats outside forest, marshes, river banks, ponds, etc.
   C. Ephemeral grasslands on soilless wastes, sand banks, etc.
   D. Village grazing grounds

Part II.—The principal grassland types are related to the corresponding woodland types as recognised by Champion. Each type is related to climate, locality, geology and soils, biotic features, floristics and ecology.

Part III.—The grasslands of forests and other specialised habitats are included in (A) dry 'sal' forests, (B) moist 'sal' forests, (C) subtropical chir pine forests, (D) moist deodar forests, (E) Western mixed conifiers and oak-fir forests, (F) Himalayan oak forests, (G) dry bamboo brake, closed forests and forest margins, moist habitats outside forest, ephemeral grasslands and village grazing grounds.

Part IV.—Habitats of the common grasses of Uttar Pradesh have been studied.

Grasslands of Assam

By M. L. Saikia

Destruction of forests by fire and other human activities has resulted in the development of Savannahs in the plains. Other types of grasslands are also found along river banks and swamps. However, the hill grasslands resemble the Nilgiri grasslands which develop on shallow and humus rich soils arising out of igneous rocks. Here the climate approximates that of the temperate regions.

The grasslands of the plains are classified into (1) riverain or 'Chapari' type, (2) swampy or 'Bheel' type and (3) highland savannahs and those of the hills into, (4) dry hill type and (5) wet hill type. Each type is studied in relation to climate, geology, rock and soil and ecological status.

The Ecological Status of the South Indian Grasslands

By K. N. Raghavan Nair

The forest vegetation of the Western Ghats and the extensive grasslands of the Nilgiris have been studied along with the rock and soil, climate and rainfall and exposure.

The 'Sholas' (evergreen forests) are chiefly represented by Myrtaceæ, Lauraceæ and Styraceæ. The undergrowth consists of mainly *Strobilanthes*. Eighteeen species of grasses are commonly found. An exotic grass—*viz.*, *Pennisetum clandetinum* has recently been introduced as a fodder grass and is spreading very rapidly over the region.

Afforestation of the grasslands with 'Shola' species tried from 1934 onwards indicates that the 'Shola' species can grow and regenerate under a frost cover provided by *Cytisus scoparius*. This lends support to Champion's view that the grasslands followed removal of the forest vegetation.

The Ecology and Seasonal Aspect of the Phanerogamic Flora of the Irrigation Tanks about Dharwar

By H. R. Ladwa

Fresh-water tanks in India have in recent years been subjected to detailed and interesting research but most of the work has centred

around the zooplankton and the phytoplankton, since the latter forms the integral part of the food of fish. Except for the works of Dudgeon (1920), Saxton (1924), Biswas (1927) and Misra (1946), there seems to be very little work done on the aquatic and marsh flora of tanks in India and particularly there is no record of any ecological work done on the aquatic and marsh flora of the tanks of Bombay-Karnatak.

The topography of Dharwar being hilly, a fairly large number of tanks are found in the valleys within easy reach of the town. Many of them are used for irrigation purposes but only for a short period during the year. Of these, four tanks which are within a radius of about five miles from the town were selected for study.

The tanks show two distinct aspects, *viz.*, 'The Dry Phase' and 'The Aquatic Phase'—the former alternating with the latter. The duration of each phase varied from tank to tank; the dry phase being longer in the shallow annual tank. The nature of succession in the perennial tanks is both auto- and allogenic.

The distribution of the vegetation is correlated with the physiographic factors such as steepness of slopes, mouths of inlets, shelter, depth of water and biotic factors. It was found that the number of plants distributed in the various tanks is related to age and area of each tank except in Kelgeri. A comparison of the vegetation of the different tanks showed certain differences in their floristic composition and the probable causes of such differences are complex.

Studies in the Hydrophytes of Jodhpur

By Shanti Sarup

Jodhpur is situated on the fringe of the Desert. The climatic factors are very adverse. The temperature is high and rainfall is scanty. The rain-water is conserved in artificial tanks in the rocky valleys and in the plains also. Blatter and Halberg reported nine species of water plants from this area.

The occurrence of *Najas australis* and *N. welwetchi* is interesting, both plants being new for India.

Fifty-seven species belonging to 17 families and 40 genera have been recorded besides species of *Chara* and *Marsilea*. Three aquatic associations, *viz.*, *Eichhornia-Potamogeton* association, *Hydrilla-Vallisneria* association, *Ceratophyllum-Vallisneria* association, have been recognised.

Natural Flora as an Index for Soil Classification in Semi-Arid and Arid Zones

By C. L. Dhawan and J. C. Bahri

Soils from typical areas of semi-arid and arid zones of the Punjab, colonised by eleven types of natural flora and land devoid of any vegetation, have been studied.

The following natural flora serve as an index for judging the quality of land from the point of view of fertility and deterioration.

(i) *Prosopis spicigera*, *Salvadora oleoides* and *Zizyphus nummularia* are indicators of good land.

(ii) *Calotropis procera*, *Saccharum munja* represent sandy soils. *S. munja* is also associated with high water-table either continuous or occasional.

(iii) *Peganum harmala* is also indicator of normal lands. But due to increase of soluble salts with depth, special care has to be taken in crop production.

(iv) *Tamarix articulata*, *Butea monosperma*, *Capparis aphylla* represent saline soils, which need reclamation.

(v) *Anatherium muricatum*, *Suæda fruticosa* soils and lands devoid of any vegetation are highly deteriorated and require intensive reclamation.

The Halophytes of the Indian Desert

By Shanti Sarup

Alkaline soils are characteristic of regions where desert conditions prevail. Important alkaline lakes of India—Shambhar, Didwana, Pachpadra and Lunwaransar are situated in the area. Besides these regular lakes there are other areas also where saline water of various specific gravity occurs. The waters of Luni River are saline. Thus the salinity of the Rajasthan Desert is widespread and extensive.

Origin of salinity is not understood. It is supposed to be due to (1) decomposition and weathering of the rocks, (2) huge quantities of salt are brought by the action of winds from the saline concentrations of the Rann of Cutch, (3) saline material is largely due to regional leaching and concentration in land basins. There are other usual causes for the aridity of the regions. The salinity of the soils of different places varies in nature and chemical composition. The salts generally found are sodium chloride, sodium bicarbonate and calcium sulphate. The pH of the soils varies from 7·5 to 9·5.

Tamarix dioca Roxb. and *T. gallica* var. *articulata* Vahl., grow gregariously on the banks of the saline depressions. Some of the other halophytes are: *Chenopodium album* Linn., *Atriplex cressifolia* Mey, *Suæda fruticose* Forsk., *Haloxylon salicornieum* Bunge, *H. multiflorum* Bunge, *Salsola fætida* Del. No zonation has been noted in any of the localities.

Plant Ecology of the Indian Desert in Retrospect and Prospect

By Shanti Sarup and M. L. Bhandari

Three ecological zones in the Indian Desert have been described: (1) *Arawali hills* (south and south-east region over the Arawali hills.

Here some natural vegetation is found). (2) *Semi-arid region* (about 100 miles parallel to the first region. Here plants of the most xerophytic type are found). (3) *Arid region* (to the extreme-north and west of the above. Here the vegetation is very poor). The vegetation has been treated as that of dune, gravel, rocks, aquatic and semi-aquatic. The salt problem and the halophytes are studied. Besides, soils and vegetation, climate, archæology and afforestation of Indian desert are indicated. Practical steps so far taken and some other problems in the immobilisation of the desert are also studied.

Sand-Dune Vegetation of Pilani and Its Neighbourhood

By N. C. Nair and M. C. Joshi

The area under investigation has been divided into two regions. The first constitutes the town of Pilani, the cultivated fields close to it and Vidya Vihar. The second region is sandy and consists of three areas: those with moving sand-dunes, with stationary sand-dunes and dune-free areas. The ecological features of these areas and the factors governing plant growth have been studied. They are similar to other arid regions of Rajputana. The principal flora of each of the three areas are:—

1. Sand-dunes of the moving type:

   Calotropis procera, Crotalaria burhia, Aerua tomentosa, Citrullus colocynthis, Cyperus arenarius, Indigofera argentea, Leptadenia spartium, Calligonum polygonoides, etc.

2. Stationary sand-dunes:

   Prosopis spicigera, Tecoma undulata, Acacia spp., *Capparis aphylla, Gymnosporia montana, Zizyphus rugosa, Calligonum polygonoides, Boerhaavia diffusa, Eragrostis* spp., *Cynodon dactylon,* etc.

3. Dune-free areas:

   Calotropis procera, Panicum turgidum, Citrullus colocynthis, Eleusine flagellifera, Zizyphus xylopyrus, Boerhaavia, Tribulus, Trianthema, Cynodon, etc.

Vegetation Types in the Kumaon Himalaya with Special Reference to the Panch Chulhi Area

By M. B. Raizada and K. C. Sahni

An account of the different types of forests and vegetation met with in a narrow strip of the Kumaon Himalaya, *viz.*, Panch Chulhi (Lat. 30° 13′) and its vicinity that was explored in 1951 is given in this paper. The area exhibits regions ranging from sub-tropical through temperate to alpine and arctic. The changes in flora are marked by well-defined zones of altitude. Climate and geology of the area are

dealt with. The rock debris of the glaciers gives a clue to the composition of the Panch Chulhi range. The morainic material consists of metamorphic rocks, largely slates and schists banded with granite. The glaciers descend to below 3050 m. in Fir forests. It is very likely that they are the lowest glaciers in the Himalayas. The notable plants of the high mountain flora of Panch Chulhi are *Saxifraga imbricata* Royle, a cushion-like herb at 5,790 m., *Sedum crenulatum* Hk. f. & Th. and *Primula macrophylla* D. Don. The last named species is mostly confined to heights of 3,100–4,300 m. The vegetation is differentiated into distinct types which are easily separable. They are classified as follows:—

Cypress forests, mixed forests, fir forests (high level and low level), alpine scrub, alpine meadow, vegetation of the stony desert and vegetation around perpetual snow. The Cypress forests are characterized by scattered groves mostly on limestone soils. The mixed forests extend considerably on northern aspects on dip slopes with deep moist soils. The tree species are mostly deciduous and are composed of *Aesculus indica* Colebr., *Acer pictum* Thunb., *Quercus incana* Roxb., etc. The understory and the ground flora of the different types of forests are listed. The change from a mixed forest to the low level Fir forest is well marked. The latter is confined to altitudes of 2,400–3,050 m. The high level fir extends from 3,300–3,810 m. Vegetation in alpine meadows, stony desert and around perpetual snow has been studied.

Vegetation types for the Kumaon area in general are more briefly described. This area is divisible into five belts. The first regional belt comprises the sub-Himalayan tract composed of recent beds of boulders, gravel and silt brought down by Himalayan streams. The second stretches from the base of foot-hills to the crest of the outermost range. The third regional belt stretches from crest of the outermost range to the main where a botanical survey was carried out. Passing north of the range is the fourth regional belt where the amount of rainfall decreases abruptly. Finally there is the narrow belt of country bordering Tibet that comprises the fifth regional belt.

The Vegetation of Sagar, Madhya Pradesh

By R. Misra

The geographical, physical, climatic, geological and edaphic conditions of Sagar are studied. The terrain is well drained with an average annual rainfall of 125 cm. The climate is suitable for a climax of monsoon deciduous forest. Three growth initiation periods and one of least growth are recognised. The soils are black 'regur', red sandy and alluvial in character.

The types described in the paper in relation to their ecological conditions are:—

I. Forests

(*a*) *Diospyros melanoxylon—Butea monosperma* type.

(2) *Anogeissus latifolia—Diospyros—Terminalia tomentosa* type.

(3) *Tectona grandis—Anogeissus latifolia* type.

(4) Riverain types—

(*a*) *Madhuca latifolia—Diospyros melanoxylon.*

(*b*) *Eugenia heyneana—Terminalia glabra—Ficus glomerata.*

II. Scrub jungles.

III. Grasslands

(*a*) Dense rolling monsoon grasslands.

(*b*) Grass fillings within forests.

(*c*) Grazing lands.

IV. Aquatic, marsh and low-lying land vegetation types.

V. Village side vegetation types.

The Vegatation of Bombay

By F. R. Bharucha

A brief account of geographical, geological and climatic features of the Bombay Island have been given.

The climax vegetation of Bombay is a mixed deciduous forest with *Tectona grandis* and *Terminalia tomentosa* forming about 50% of the trees. Depending upon the intensity of biotic exploitation the deterioration of the forests results in scrub jungles, grasslands and weed vegetation. Regression of the forests to the *Blumea eriantha* weed vegetation has been indicated.

Two main ruderal types have been described. On nitrate rich soil the typical vegetation is dominated by *Amaranthus spinosus*, elsewhere on dry clean roadside the vegetation is dominated by *Cassia tora*. Besides, calciphilous association has also been discussed.

The characteristic halophytic mangrove vegetation found all along the coast of Bombay has been studied. The most dominant species is *Avicennia officinalis*. The less hydrophytic vegetation has also been described. The characteristic vegetation of ponds and tanks that do not dry up, the vegetation along the edges of ponds and that of the drying ponds are also described.

Vegetation Types in Western India

By H. Santapau

The types of vegetation in Western India, from North Kanara to Saurashtra, have been studied.

1. Evergreen forests of North Kanara:

   Forests of Dudh Sagar. Forests near Gersoppa Falls. The forests at Dandeli, N. Kanara.

2. The monsoon flora in the neighbourhood of Bombay:

   Senecio Grahami in Khandala; Plietesial plants in Khandala (*Carvia callosa*), Zingiberaceæ of Bombay and other monsoon gregarious plants.

3. Types from Saurashtra:

   The riverain flora in the Gir Forest, the seashores near the Somnath temple, reclamation of seashores, *ibidem*. The dry semi-desert flora of Chotila.

4. Other types with representative plants:

   Epiphytes; insectivorous plants; parasites; water plants, etc.

Vegetation Types of the N.-W. Himalayas

By G. S. Puri

North-Western Himalayas may be conveniently divided into three zones:—

(i) Outer Himalayas, represented by Mussoorie, Chakrata, Simla, etc., characterised by high monsoon rainfall, little snowfall and high temperatures in summer.

The main rocks are shales, limestones, schists and quartzites.

The climatic climax in this zone is *Quercus incana*. The association may be pure or mixed with numerous lauraceous species, *Rhododendron*, *Pieris*, etc.

Pinus longifolia, *P. excelsa* (and rarely *Cedrus deodara*) are the chief conifers either confined to special rock types or the result of biotic interference.

The vegetation on the dip and scrap slopes is often distinct. Scrap slopes bear xerophilous or scrubby vegetation as against hygrophilous types of the dip slopes.

(ii) Middle Himalayas, represented by Kulu District, Lower Bashahr, parts of Chakrata District, etc., is the zone of feeble monsoon rainfall, heavy snowfall and low temperatures throughout the year.

The main rock types are schists and phyllites, though quartzite and granites also occur. The strata of the rock show conspicuous dips and at many places fall in zone deposits are covered over by flood plain deposits or glacial moraines.

The climatic climax at lower levels is *Quercus incana—Q. dilatata* and at higher levels *Q. semecarpifolia.*

The *Q. incana* and/or *Q. dilatata* communities are associated with a number of broad leaved species, besides *Rhododendron.* There are *Acer*, cherry, poplars, walnuts, elms, horse chestnuts, etc.

On flood plains or scree deposits conifers—*Pinus excelsa* and *Cedrus deodara* occur, as also on abandoned cultivation. The progression of these types of oak climax is slow and uncertain due to continued disturbance.

The *Q. semecarpifolia* community at higher levels is almost pure, with *Betula utilis* or a few broad-leaved species occurring rarely in it.

In glaciated regions *Abies webbiana* community with a number of broad-leaved species occur. This is seral and its progression to oak climax is again slow and uncertain.

There occur open pastures, which are degraded oak forests.

Vegetation types on dip and scarp slopes are distinct.

(iii) Inner Himalayas, represented mainly by Upper Bashahr is a zone of low monsoon rainfall, high snowfall, moderately high summer temperatures.

The main rocks are granites, gneiss, quartose-granites, though schists also occur. The strata of the rock, though show dips, these being highly metamorphosed and compacted have no seepage planes. Scree deposits, landslides, flood plain deposits and glacial moraines occur. Old flood plain deposits occur at very high altitudes, upto 10,000 feet.

The climax is *Quercus ilex.* The community may be rarely associated with *Fraxinus xanthoxyloides.*

Cedrus deodara occurs mainly on high level flood plains. *Pinus excelsa* and *Abies webbiana* occur on glacial moraines.

On new alluvium of granite rocks at lower levels, there occur seral communities of *Pinus gerardiana.* This is quite conspicuous on abandoned cultivation.

On alluvium of schists at lower levels is found a seral community of *Cedrus deodara.*

There are a number of pastures, in this zone too, which are degraded forests.

Besides these there are a number of communities of broad-leaved species in all the three zones, which occupy new alluvium along rivers or small or large streams. These are seral but due to their special environment, progression to the climax is slow or none at all.

Summarising, the climatic climax in the North-Western Himalayas is the oak forest of one or the other species. The conifers occupy special habitats and are seral in nature. The progression to the climax type is determined by the nature of the habitat, chiefly the soil.

Vegetation Types in the Siwaliks between the Ganges and the Jamuna

By G. S. Puri

The Siwaliks between the Ganges and the Jamuna bear a mixed deciduous forest in which *Shorea robusta* is one of the most important species. The vegetation is related closely to the geological and gross soil features. It is recognised to fall into the following types:—

(i) Conglomerate *types*.—In their best conditions conglomerate types constitute an open type of mixed deciduous forest of *Shorea robusta—Anogeissus latifolia*, *Anogeissus—Terminalia*, *Terminalia—Shorea*, and *Pinus longifolia—Anogeissus* community developed mainly on scrap slope.

On dip slope of the conglomerate the forest has a higher proportion of 'sal'. The climax types on this slope is a mixed deciduous forest with little 'sal'.

An open grassy vegetation, with or without trees, is a degraded climax type, which at some places represents a secondary succession also.

This habitat is generally dry.

(ii) Clay types are composed of *Shorea robusta.—Eugenia jambolana*, *Shorea—Terminalia tomentosa*, *Shorea—Ougeinia* communities, which are distributed according to the level of soil moisture, organic matter and exchangeable Ca.

On the scrap slope *Shorea-Terminalia* community, which has also fair amounts of *Anogeissus latifolia* and other *Terminalias* has a grassy undergrowth. But on the dip slope, the undergrowth consists of a number of evergreen dicotyledonous species and *Adiantum*. *Mallotus* is more common in these types together with *Litsea*, *Ehretia*, etc.

There are several degraded types of communities with scattered growth of *Cassia fistula*, *Zizyphus*, *Holarrhena*, *Casearia tomentosa*, etc., on the dry slope. The grassy flats here are dry. On the dip slope, however, grassy flats, known as 'Tappars' are damp and even at places are water-logged.

At those places on the dip slope where seepage water is available in abundance an evergreen type of forest with *Holoptelea*, *Putranjiva*, canes and tall ferns is developed.

(iii) *Alluvial types*.—On the fresh alluvium of the Song and Suswa rivers *Acacia-Dalbergia* community is met with in shingly and gravelly

soil. On finely divided soil with clay and silt, *Trewia—Holoptelea—Bombax* community is developed. *Tamarix* community is developed on sandy saline soils.

Due to biotic interference and erosion the alluvial types have also a number of degraded types that are represented by a heterogenous open forest with an odd tree or two of *Adina cordifolia, Stephegyne, Shorea, Terminalia* along with new species of alluvial habitats and scrub species of *Zizyphus, Randia, Limonia acidissima, Aegle marmelos,* etc.

The types on the three types of habitats are not related successionally, though on account of mixture of soil some species may be common in these. The climax vegetation is a mixed deciduous forest, the various associations of which are related primarily to special types of substrata.

Torrent Reclamation by Means of Vegetation in North Bihar

By R. Maclagan Gorrie

Stream water during the rainy season cuts through sloping land gullies, and sand drifts down to cultivated fields. The smaller local streams thus arising cause more damage to the fields than the larger rivers. Terrace wall of turf and stone should be built and ploughing should be done along the contour. Reduction in grazing, covering the land with vegetation and protection against fire are suggested for such areas.

Live hedges of sand loving plants such as *Vitex negundo, Ipomea carnea, Ficus religiosa* and even *Lantana* should be grown in short lengths running downstream but towards the centre at about 30° from the margin. *Saccharum spontaneum* and *S. munja* are also useful in the early stage. Growth of trees and bushes following the shelter belts further consolidate them. This method has been practised with success in Hoshiarpur District. The old sandy bed could be made into good loam after a few years under a crop of sissoo, khair and simul trees.

REVIEW

Common Medicinal Plants of Darjeeling and the Sikkim Himalayas. By Dr. K. Biswas. (Superintendent, Government Printing, West Bengal Government Press, Alipore, West Bengal), Price Rs. 7.

From time immemorial, the medicinal properties of the plants of our vast and luxurious flora were well known. Books on 'Materia Medica' formed an integral part of our literature, but systematic compilation of information on the flora as well as on medicinal plants dates back only to the time of the advent of the foreigners. Several excellent treatises on this subject were published from the mid-fifteenth century onwards, but due to the vast area to be covered the flora of many parts of India were left unexplored or incompletely studied. Though Sikkim and Darjeeling were exceptional in attracting a large number of botanists and naturalists, a systematic study on medicinal plants of this area was not so far attempted. It is therefore highly gratifying to note that such a competent authority as Dr. Biswas has brought together all available information on the subjects in his monograph.

The book under review contains studies on 147 medicinal plants common to Sikkim and Darjeeling. The botanical description of each plant is followed by discussions on its distribution, medicinal properties and uses. Wherever possible, the chemical constituents of drugs are also mentioned. Vernacular names of the medicinal plants are given and in a few instances reference is made to their Sanskrit equivalents. This has made it useful to practitioners of the Ayurvedic system too to some extent. The book also contains a valuable introductory chapter entitled 'Herbal charms' and presents much useful information regarding nomenclature, classification of plants and general features of the vegetation of Darjeeling and Sikkim. Fifty well got-up plates of drawings of plants show clearly their external morphological features and make identification easier. It can be said without any hesitation that the book is a valuable addition to the literature on medicinal plants.

K. Narayana Iyer.

ANNOUNCEMENT

The Ninth International Botanical Congress will be held in Montreal, Canada, from August 19 to 29, 1959, at McGill University and the University of Montreal. The program will include papers and symposia related to all branches of pure and applied botany. A first circular giving information on program, accommodation, excursions, and other detail will be available early in 1958. This circular and subsequent circulars including application forms will be sent only to those who write to the Secretary-General asking to be placed on the Congress mailing list:

DR. C. FRANKTON,
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